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Souris River Automatic Water Quality Monitoring

1977 - 1982

Report 1: Preliminary Data Evaluation

June 1984

SOURIS RIVER AUTOMATIC WATER QUALITY MONITORING
1977 to 1982

Report 1: Preliminary Data Evaluation

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PREFACE

The Water Quality Branch, Environment Canada, operated automatic water quality monitors at two location on the Souris River during the period 1977 to 1982, for the purpose of providing continuous water quality data for four physical variables.

The results of the study are presented in two reports:

Report 1: Preliminary Data Interpretation presents and discusses the water quality data gathered during the study period.

Report 2: Evaluation of the Automative Monitors provides a discussion of the use of automatic monitoring for the collection of baseline data.

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1.0 INTRODUCTION

The Water Quality Branch, Environment Canada, initiated automatic water quality monitoring (auto-monitoring) at two locations on the Souris River in 1977 and 1978. The program consisted of continuous auto-monitoring for four physical variables supplemented by monthly manual sampling for a broad spectrum of water quality variables. The auto-monitoring portion of the program was discontinued in June 1982.

The major objective of the program was to provide continuous water quality data for use as a baseline against which potential future effects of the Garrison Diversion Unit Project (GDUP) could be assessed and/or predicted. A second objective was to evaluate the use of automated equipment as a monitoring tool. This paper presents the data collected during the period 1977-1982 and evaluates their adequacy in meeting the major objective. The problems and benefits associated with the use of automatic water quality monitors are discussed in Report 2: Evaluation of the Automatic Monitors.

1.1 Background

Construction of the Garrison Dam on the Missouri River in North Dakota was completed in 1956. The resultant reservoir (Lake Sakakawea - 18 milliom dam3) was designed to provide water for hydroelectric power generation, recreation, and the irrigation of approximately 400,000 hectares of farmland.

Congress approved funding for the initial development of the irrigation project (GDUP) in 1965. The first phase involved the irrigation of 100,000 hectares of land in the Souris Loop and Devil's Lake regions. Construction of the GDUP was initiated in 1968.

The interbasin water transfer aspect of the project has been the focus of Canadian concern for a number of years. Irrigation return flows from the Souris Loop and Devil's Lake areas may discharge into the Souris and Red Rivers, either directly or through tributary streams. Such return flows could have deterimental effects on the water quality of both rivers.

The United States and Canada, under the Boundary Waters Treaty of 1909, are obliged in that:

> ". . . waters herein defined as boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other."

Concern over the impacts of the GDUP on receiving waters has prompted the preparation of a number of assessments over the past years by both the Canadian and United States governments as well as by other interested groups. From these assessments, a consensus has been reached in that changes in a number of water quality variables will occur. There is incomplete agreement; however, as to the magnitude and environmental significance of these changes.

The major probable effects on the water quality of the lower Souris River resulting from irrigation in the Souris Loop (International Garrison Diversion Study Broad, 1976a) include the following:

1. Levels of total dissolved solids (TDS) will increase by approximately 50% in the Souris River. Major causative factors will be increased levels of sulphate and total hardness. Increases in TDS will be especially acute during the pre-equilibrium years, perhaps the first ten, due to leaching of newly exposed soils;

2. Levels of nutrients, primarily nitrogen and phosphorus, will increase due to inefficiencies in fertilizer application and the introduction of new potential waste sources, such as feedlots, recreational facilities, and crop processing facilities;

3. Levels of suspended sediments will increase resulting from erosion of irrigated lands, channels, and canals, especially during the pre-equilibrium period;

4. Levels of pesticides may increase as a result of more intensive agricultural use of land;

5. Alteration to dissolved oxygen regimes will occur due to increased flows; and

6. Interbasin transfer of biological organisms could have serious impact on the biota of receiving streams and lakes.

The data collection program initiated in 1977 addressed two of the above-listed variables, total dissolved solids and dissolved oxygen. Also monitored were the related variables water temperature and pH.

1.2 Study Area

The Souris River originates in southeastern Saskatchewan and flows in a southeasterly direction, crossing the United States Boundary near Glen Ewen, Saskatchewan (Figure 1). The river continues its southeasterly course to Minot, North Dakota, then turns to the east and northeast, re-entering Canada near Coulter, Manitoba. The lands in North Dakota encompassed by the Souris River and the Canadian border are commonly referred to as the Souris Loop area. The Souris River joins the Assinibione River near Wawanesa, Manitoba, which discharges into the Red River at Winnipeg, Manitoba.

Total gross drainage area for the Souris River near Coulter is 43,146 km2, with an effective drainage area of 13,291 km2 (Prairie Farm Rehabilation Administration, 1978), of which approximately 54 per cent is in the United States. Flows in the Souris River are extremely variable with short duration spring runoff (usually in April or May) and very low flow through the remainder of the year. Total annual discharge at the eastern border crossing has varied from 136 dam3 in 1937 to 1,450,000 dam3 in 1976, with a mean (1929 to 1979) of 240,000 dam3 (Water Survey of Canada, 1980). Under an interim flow apportionment agreement of 1959, Saskatchewan is required to maintain a flow of 0.11 m3/s at the point where the river enters the United States

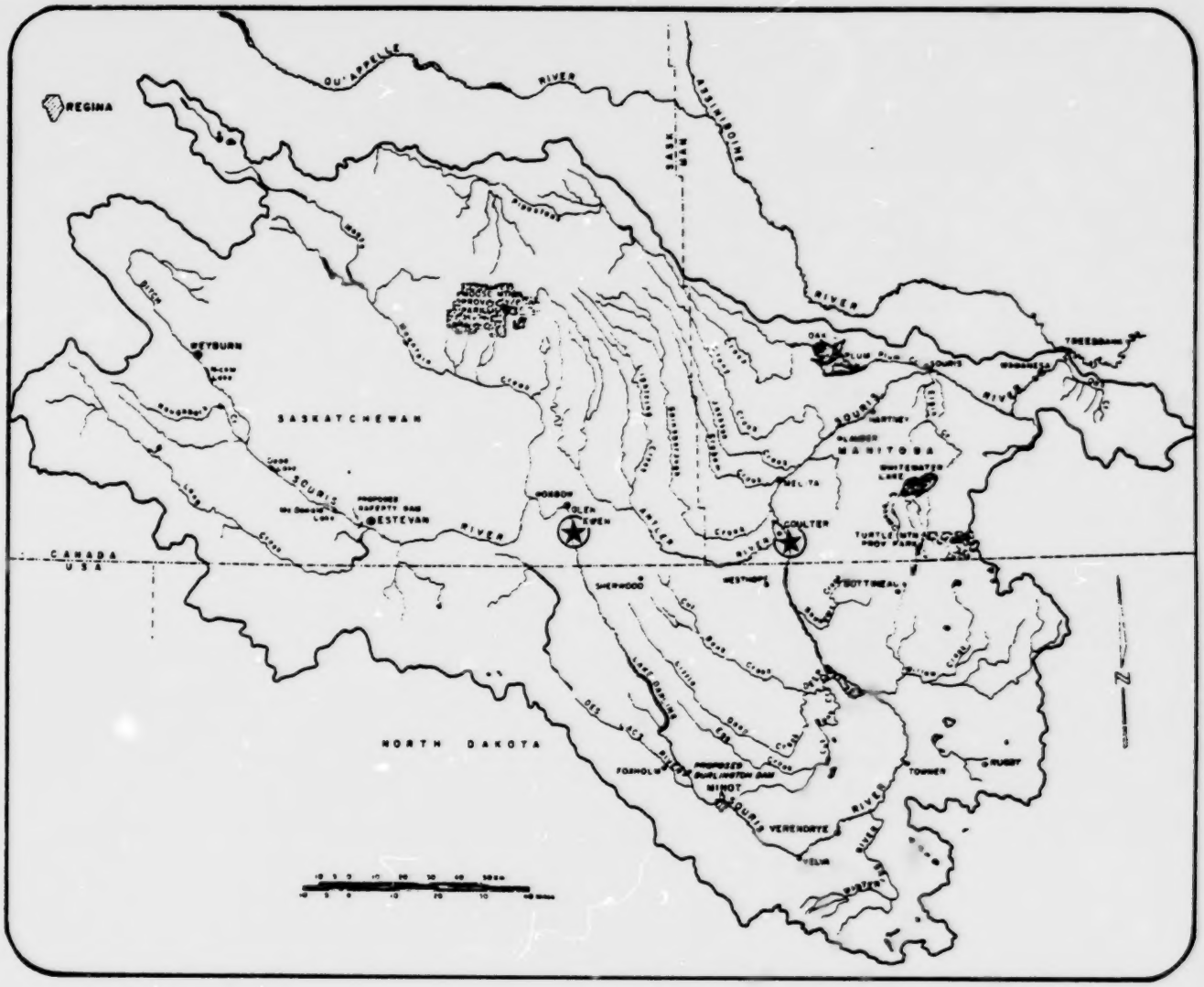

Figure 1. Souris River Automatic Monitor Sites

provided that such flow would have occurred prior to construction of Boundary Dam on Long Creek. North Dakota is required to maintain a flow of 0.57 m3/s at the point where the river re-enters Canada during June to October inclusive, except during periods of severe drought. During periods of severe drought, North Dakota is required to provide adequate flows to accommodate human and livestock consumption and household use.

2.0 METHODS

Two monitoring locations were established on the Souris River near the international boundary, above and below the Souris Loop. The upstream station was situated near Glen Ewen, Saskatchewan (Lat. 49° 11' 02" N, Long. 102° 01' 42" W), and the downstream station near Coulter, Manitoba (Lat. 49°05' 27" N, Long. 100° 57' 12" W). The stations were co-located with hydrometric gauging stations operated by Water Survey of Canada (station numbers 05ND001 and 05NF016, respectively). The monitors were installed on August 11, 1977 at Glen Ewen and April 7, 1978 at Coulter.

Philips model PW9835 automatic water monitors were installed to provide continuous monitoring of four physical variables: water temperature, specific conductance (compensated to 25° C), dissolved oxygen (DO), and pH. Employing a continuous flow-through probe block and self-standardization, the Philips monitors were designed to provide low maintenance, continuous recording of up to six variables.

The monitors were located in insulated steel shelters fitted with heaters and air conditioners to maintain the inside air temperature between 15°and 25°C throughout the year. At the Glen Ewen site, the monitor was situated on the river bank approximately 15 meters from the normal shoreline and four meters above the mean water surface. During most of the study, the intake orifice was located near midstream. The intake line was housed in an underground steel pipe leading to a hydrometric well located on the shoreline. From the hydrometric well to the monitor shelter, the heat traced intake line passed through an insulated utilidor. The total distance from the intake orifice to the monitor was approximately 25 meters. On occasion fouling of the intake lines necessiated the use of submersible pumps and surface intake lines.

The Coulter monitor was located on an abandoned highway bridge approximately five meters above the normal water level. The intake was housed in a steel culvert which was suspended below the monitor shelter directly into the river.

In 1979, each monitor was fitted with a data collection platform (DCP) to provide automatic transmission of results via satellite to a receiving station in Maryland, thus allowing immediate retreival and viewing of the monitor data. The monitoring system is illustrated in Figure 2.

Data from the monitors were retrieved daily, and stored in the Water Quality Branch computer located in Regina. Monthly monitor reports were prepared for each station, including daily and monthly means for each variable. Prior to the preparation of the monthly

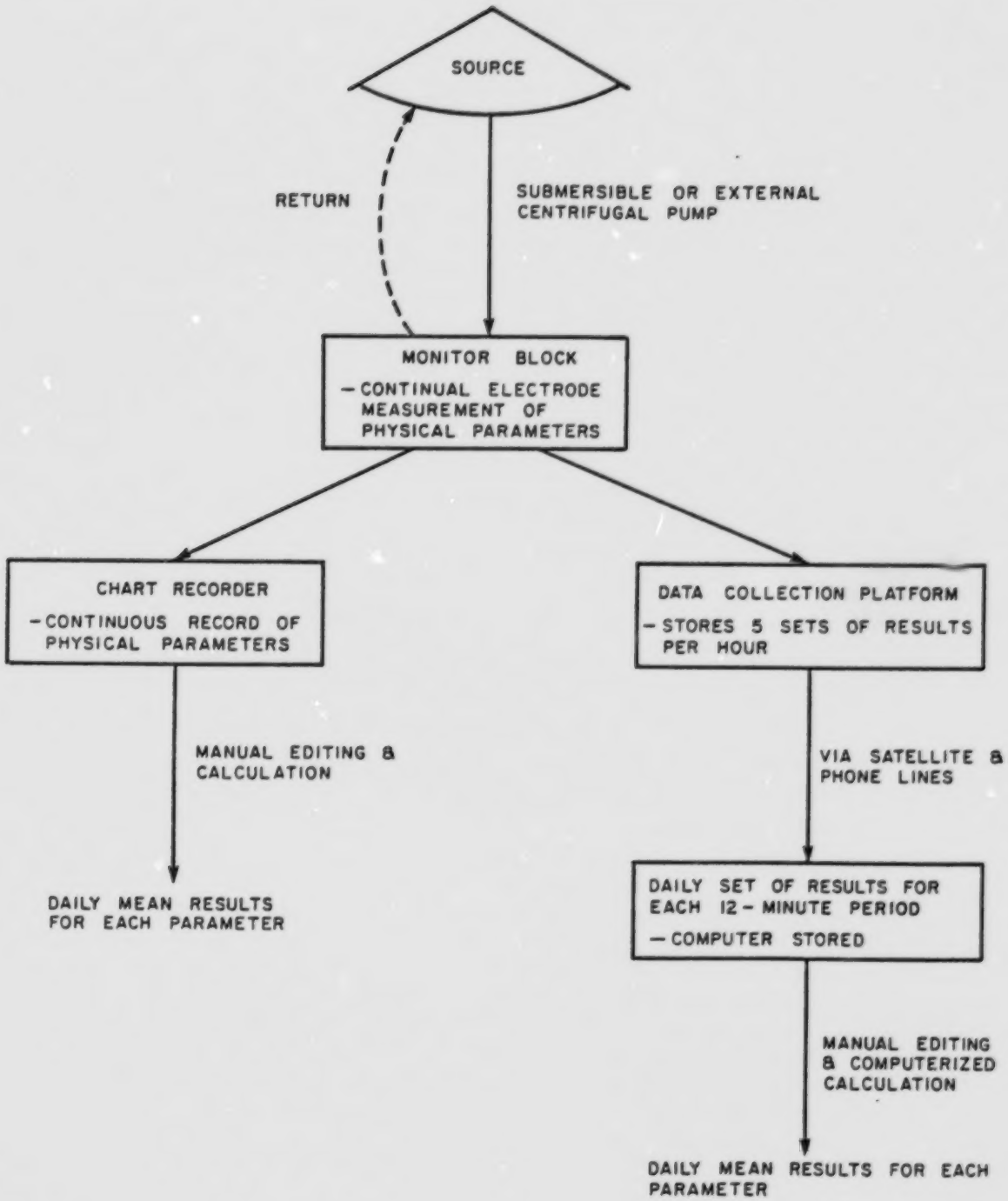
SOURCE
RETURN
SUBMERSIBLE OR EXTERNAL CENTRIFUGAL PUMP
MONITOR BLOCK
- CONTINUAL ELECTRODE MEASUREMENT OF PHYSICAL PARAMETERS
CHART RECORDER
- CONTINUOUS RECORD OF PHYSICAL PARAMETERS
DATA COLLECTION PLATFORM
- STORES 5 SETS OF RESULTS PER HOUR
MANUAL EDITING & CALCULATION
VIA SATELLITE & PHONE LINES
DAILY MEAN RESULTS FOR EACH PARAMETER
DAILY SET OF RESULTS FOR EACH 12 - MINUTE PERIOD
- COMPUTER STORED
MANUAL EDITING & COMPUTERIZED CALCULATION
DAILY MEAN RESULTS FOR EACH PARAMETER

Figure 2 - Schematic of the Data Collection Procedure Using Automatic Monitors.

monitor reports, manual editing of the data was necessary to remove obvious errors resulting from monitor or transmission problems. An attempt was made to reject only those data known to be in error due to specific and understood causes.

Prior to the breakdown of the automatic daily standardization process, manual shift corrections were applied to the data to correct for probe drift. It was felt that this drift could be assumed to be linear over a 24 hour period, and simple interpolation was applied. Subsequent to the loss of automatic daily standardization, it was not possible to assume linear drift between infrequent manual calibrations. Therefore, from 1979 onwards, shift corrections were not applied, reducing the confidence in the accuracy of the data.

Scheduled monthly maintenance was performed at each monitor. This included cleaning and general trouble-shooting of all equipment including pumps, lines, monitors, and DCP's, and calibration of the monitor's output. In addition, nonscheduled maintenance was performed when data transmissions indicated malfunction.

Problems with the self-standardization systems became obvious shortly after the monitors were installed. Mechanical slides located within the monitor block, used to isolate the measurement probes within separate chambers for the daily standardization process, were found to be prone to sticking due to fouling with suspended matter. After several months of operation, the slides began to wear, allowing standard solutions to leak into the monitor blocks. It was necessary thereafter to rely on manual calibration which was performed during scheduled and nonscheduled maintenance trips, an average of three times

per month.

In addition to the auto-monitoring portion of the program, monthly hand collected samples were taken at each monitoring site to provide broad parametric coverage, and to allow comparisons with auto-monitoring results.

3.0 RESULTS AND DISCUSSION

In order to present and analyze the large data base generated by the monitors during their operation, daily mean results were calculated for each variable. Daily means were calculated only for those days with twelve or more hours of data. Reducing the raw data to daily means caused some loss of information, most significantly regarding diurnal fluctuations. Dissolved oxygen (Figure 3), pH, and water temperature all displayed diurnal fluctuations during the summer months. Conductivity did not display significant diurnal variability (Figure 4).

Plots of mean daily results for each variable and location monitored are presented in Appendix 1. Annual data plots and hydrographs (as determined by Water Survey of Canada) are found in Appendix 2. Annual and period of record summary statistics for the two monitoring locations are presented in Table 1. Statistics based on flow regime are shown in Table 2.

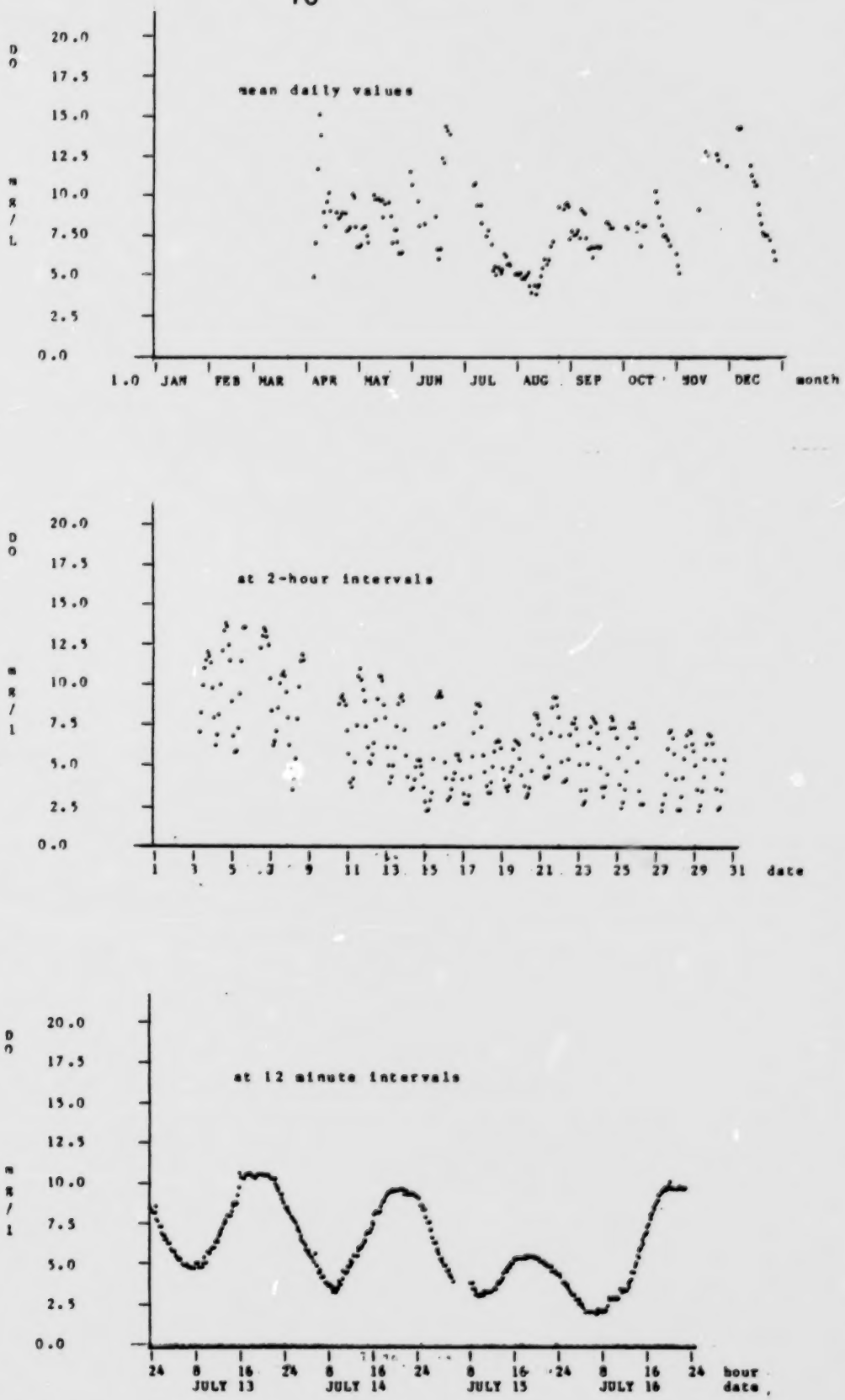
DO
mg/L
20.0
17.5
15.0
12.5
10.0
7.50
5.0
2.5
0.0
mean daily values
1.0 JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC month
at 2-hour intervals
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 date
at 12 minute intervals
24 8 16 24 8 16 24 8 16 24 8 16 24 hour
JULY 13 JULY 14 JULY 15 JULY 16 date

Figure 3. Comparison of Daily Mean Dissolved Oxygen with Two Levels of Raw Data.

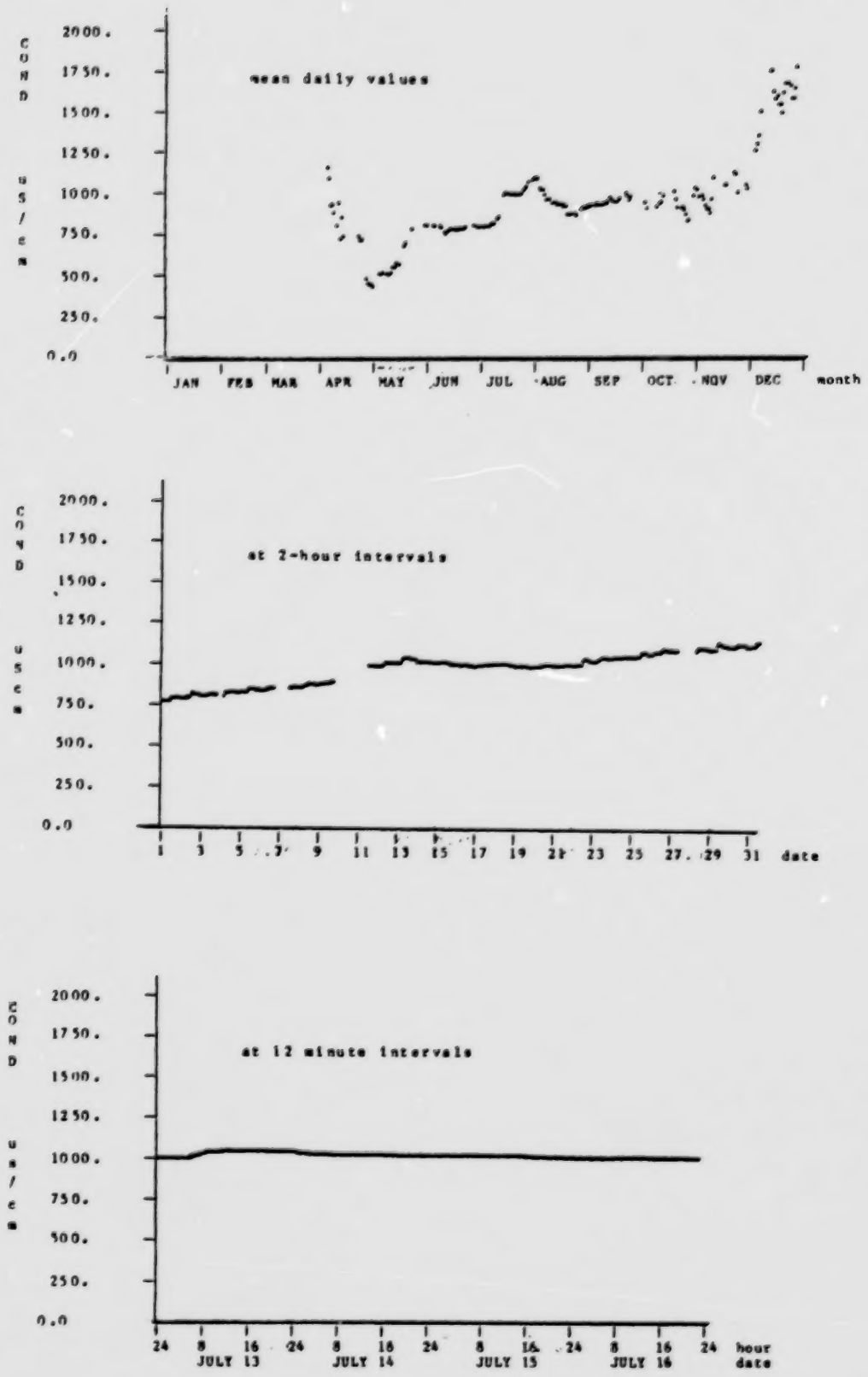

Figure 4. Comparison of Daily Mean Specific Conductance with Two Levels of Raw Data.

Table 1 Summary Statistics for Discharge and Monitor Data at Coulter and Glen Ewen

Site and Sampling Period	Daily Discharge (m^3/s) Median	Mean	St. Dev.	Min.	Max.	Total Annual Discharge (dam^3)
Coulter						
1978	0.690	4.01	5.86	0.240	31.4	127,000
1979	1.75	27.8	51.8	0.0	196.	876,000
1980	1.29	1.95	1.60	0.0	7.43	61,700
1981	1.22	2.37	2.35	0.0	10.8	74,600
1982	2.93	10.4		0.0	65.7	328,000
1978-1982	1.23	9.82	27.8	0.0	196.	
Glen Ewen						
1977	0.147	0.336	0.416	0.004	2.14	10,600
1978	1.07	4.05	7.51	0.012	46.7	128,000
1979	0.338	14.8	40.6	0.02	235.	468,000
1980	0.056	0.684	2.03	0.001	15.5	9,190
1981	0.049	0.291	1.13	0.0	9.91	21,600
1982	0.161	6.67		0.001	139.	210,000
1977-1982	0.147	4.86	20.3	0.0	235.	

Table 1 Summary Statistics for Discharge and Monitor Data at Coulter and Glen Ewen (cont'd)

Site and Sampling Period	Dissolved Oxygen (mg/L)						Temperature (°C)					
	Median	Mean	St. Dev.	Min.	Max.	No.	Median	Mean	St. Dev.	Min.	Max.	No.
Coulter												
1978	9.3	8.7	2.72	2.2	13.4	92.	8.5	10.4	7.30	0.4	26.0	102.
1979	10.8	10.5	2.17	3.1	14.9	84.	5.9	9.7	8.38	0.0	27.9	212.
1980	7.7	8.0	2.43	3.6	15.3	169.	15.7	12.7	8.13	0.0	23.8	204.
1981	7.9	7.6	3.56	0.6	14.9	249.	9.5	10.1	8.30	0.0	25.4	279.
1982	8.5	8.3	2.18	4.1	12.0	58.	17.3	16.6	3.94	7.1	22.4	58.
1978-1982	8.4	8.3	3.05	0.6	15.3	652.	11.9	11.1	8.14	0.0	27.9	856.
Glen Ewen												
1977	7.9	7.8	1.45	4.6	11.3	71.	8.8	10.4	6.09	0.6	20.0	96.
1978	7.8	8.0	2.45	3.9	14.0	118.	7.6	10.4	8.43	0.7	25.2	140.
1979	7.8	7.8	2.00	3.0	14.9	154.	12.3	11.1	7.53	0.0	23.7	216.
1980	6.6	6.5	2.44	1.0	14.6	189.	16.9	14.2	7.27	0.0	23.3	200.
1981	8.2	8.8	2.34	4.2	14.9	108.	15.4	14.1	5.29	4.2	23.4	96.
1982	7.9	7.7	1.03	5.6	9.3	45.	15.2	14.7	4.19	4.1	21.3	47.
1977-1982	7.6	7.6	2.31	1.0	14.9	684.	14.0	12.2	7.27	0.0	25.2	786.

Table 1 Summary Statistics for Discharge and Monitor Data at Coulter and Glen Ewen (Cont'd)

Site and Sampling Period	pH (pH units)						Specific Conductance (us/cm)					
	Median	Mean	St. Dev.	Min.	Max.	No.	Median	Mean	St. Dev.	Min.	Max.	No.
Coulter												
1978	8.5	8.5	0.34	7.8	9.0	104.	800.	826.	85.6	612.	1000.	84.
1979	8.4	8.3	0.56	7.4	9.3	177.	785.	853.	325.	320.	1997.	210.
1980	8.6	8.6	0.61	7.3	10.0	128.	948.	973.	284.	398.	1801.	184.
1981	8.6	8.3	0.55	7.2	9.1	270.	949.	1079.	400.	527.	2386.	255.
1982	8.5	8.6	0.15	8.4	9.0	48.	817.	801.	99.0	551.	942.	58.
1978-1982	8.5	8.4	0.53	7.2	10.0	727.	881.	947.	333.	320.	2386.	791.
Glen Ewen												
1977	8.4	8.4	0.22	8.1	9.1	96.	1397.	1406.	120.	1231.	1651.	95.
1978	8.3	8.2	0.42	7.3	8.8	69.	1001.	1010.	166.	703.	1336.	126.
1979	8.2	8.2	0.22	7.8	8.9	204.	1173.	1088.	343.	320.	1734.	210.
1980	8.3	8.3	0.28	7.6	9.2	183.	1409.	1444.	311.	483.	2142.	187.
1981	8.1	8.1	0.20	7.5	8.5	139.	1251.	1301.	208.	899.	1905.	142.
1982	8.2	8.2	0.55	7.3	9.0	46.	731.	685.	297.	260.	1069.	43.
1977-1982	8.2	8.2	0.30	7.3	9.2	737.	1238.	1213.	339.	260.	2142.	803.

Table 2 Summary Statistics for the Monitor Data During Various Flow Periods

	Glen Ewen						Coulter					
	Median	Mean	St. Dev.	Min.	Max.	No.	Median	Mean	St. Dev.	Min.	Max.	No.
Specific Conductance (us/cm)												
Spring High Flow Period	643.	698.	316.	260.	1237.	91.	687.	723.	256.	320.	1964.	204.
Low Flow Open Water Period	1260.	1240.	214.	644.	1714.	502.	894.	885.	104.	647.	1136.	413.
Low Flow Under Ice Cover Period	1583.	1530.	317.	878.	2142.	156.	1299.	1357.	407.	560.	2386.	174.
pH (pH units)												
Spring High Flow Period	8.3	8.2	0.5	7.3	9.2	93.	8.1	8.2	0.4	7.2	9.1	206.
Low Flow Open Water Period	8.3	8.3	0.2	7.7	9.1	480.	8.8	8.8	0.3	7.8	10.0	343.
Low Flow Under Ice Cover Period	8.0	8.0	0.3	7.3	8.6	124.	7.8	8.0	0.5	7.2	9.2	180.
Temperature (°C)												
Spring High Flow Period	11.5	10.7	5.6	0.1	21.9	93.	13.8	13.1	6.8	0.1	27.9	222.
Low Flow Open Water Period	17.0	15.5	5.5	0.8	25.2	520.	16.6	14.8	6.8	0.2	26.	428.
Low Flow Under Ice Cover	1.2	1.2	1.1	0.0	4.7	115.	1.2	1.2	1.0	0.0	3.8	204.
Dissolved Oxygen (mg/L)												
Spring High Flow Period	8.7	8.9	2.3	3.0	14.9	75.	8.2	8.3	2.3	3.1	15.3	161.
Low Flow Open Water Period	7.1	7.3	1.7	3.2	12.6	416.	7.9	7.9	2.8	2.2	14.8	328.
Low Flow Under Ice Cover Period	7.2	6.6	3.0	1.0	14.9	135.	10.2	8.9	4.0	0.6	14.9	163.

Flow regimes varied considerably from year to year, both in terms of magnitude and timing. In order to allow comparison of seasonal statistics , and to minimize flow related variablity in water quality, the periods in Table 2 were determined from examination of the annual hydrograph. The 'spring high flow period' was defined as the period between major shifts in the slope of the hydrograph on either side of the spring peak. This period was followed by the 'low flow open water period' which continued until ice formation. Freeze-up marked the beginning of the third period, 'low flow under ice cover', which continued until the rise in the hydrograph in spring, which always occurred under ice cover.

3.1 Discharge

During the study period, the Souris River Basin experienced wide annual variation in flow (Table 1). The range in total annual discharge in the Souris River during the study period approached the historical maximum and minimum. The total annual discharge in 1979, the highest flow year of the study, was the third highest recorded at the eastern border crossing since 1929, the historical period of record. The total annual discharge was 468,000 dam3 and 876,000 dam3 at Glen Ewen and Coulter ,respectively. Lowest total annual discharges during the study period occurred in 1981 at Glen Ewen (9,190 dam3) and in 1980 at Coulter (53,800 dam3).

Periods of no-flow occurred during the winters of 1978 and 1982 at Coulter and during the late summer and fall of 1980 at Glen Ewen. Winter flows at Glen Ewen were typically very low (less than 0.10 m3/s) with the exception of February 1980, when mild weather caused an early runoff. The discharge at both sites is subject to control. A flow apportionment agreement between Canada and the United States insures minimum discharges at both boundary crossings (see section 1.2).

The water quality data base represents a wide variety of hydrologic conditions as a result of the range in flow regimes which occurred during the study period.

3.2 pH

It should be noted that daily and long term mean pH values included in this report were calculated from actual pH results, and not from hydrogen ion concentration. The errors associated with these calculations, however, are thought to be minimal.

Over the period of record, the mean daily pH at Glen Ewen ranged from 7.3 to 9.2, with a median of 8.2 (n = 737). A few small clusters of high pH data (Figure 7 in Appendix 1) extended the upper range considerably. At the site near Coulter, pH ranged from 7.2 to 10.0, with a median of 8.5 (n = 727). At Coulter, pH in the 9 to 10 range occurred from late May to early July, 1980 (Figure 4 in Appendix 1). This period of high pH may have resulted from monitor malfunction but was not edited from the data base because specific problems were not documented. This conclusion is supported by a monthly grab sample

taken June 26,1980, which showed the pH to be 8.9.

An annual trend in pH is apparent at the Coulter site, with lowest pH occurring during the winter months (median = 7.8), and highest pH occurring in the summer (median = 8.8). The winter decline in pH is to be expected due to higher carbon dioxide concentration resulting from reduced rates of photosynthesis.

The use of the auto-monitoring pH data as an assessment tool is greatly limited due to lack of accuracy, which was discussed in 'Report 1: Evalution of the Automatic Monitors'. It is noteworthy, however, that pH in the lower Souris River is not expected to be significantly influenced by the addition of irrigation return from the Garrison Diversion Unit Project.

3.3 Water Temperature

Water temperature varied widely between seasons at both monitor locations. During the winter, the water temperature approached the freezing point and during the summer peaked near 25 C. The summary statistics in Table 1 show the mean annual water temperature at Coulter to be lower than at the Glen Ewen site. This was the result of the greater number of winter data points at the Coulter site.

The International Garrison Diversion Study Board (1976b) concluded "flows from the GDUP will quickly attain the ambient temperature of the receiving streams and thus will not alter their normal temperature regime where the streams enter Canada."

3.4 Dissolved Oxygen

Mean daily DO concentration at the site near Coulter decreased to low levels (less than 5 mg/L) for varying lengths of time each summer (Figure 2 in Appendix 1). This depression in DO was likely caused by increased oxygen demand to accomodate the biological breakdown of organic material. A significant winter DO decline occurred at Coulter during the winter of 1980-81, the only winter of continuous DO record at the site. The Souris River Basin Study (1978) reported similar depressions in DO during the winters of 1975 and 1976. Monthly grab samples taken by the Water Quality Branch (1980a,1982a and 1984a) have typically shown low winter concentration of dissolved oxygen at the site as well.

Recurrent summer declines in DO concentration were not apparent in the Glen Ewen data (Figure 8 in Appendix 1). A decline in winter DO concentration occurred during the early winter of 1980 prior to shutdown of the monitor. A similar trend was noticeable prior to monitor shutdown in December, 1978. Unfortunately, the routine winter shutdown of the Glen Ewen monitor makes assessment of winter trends in DO impossible. However, monthly data (WQB 1980b, 1982b and 1984b) show that DO concentrations typically decline during the winter months.

Diurnal fluctation in DO concentrations of 8 mg/L were not uncommon during the summer months at both sites. Lowest DO concentrations occurred in the early morning, with concentration often declining to 2.0 mg/L (Figure 2). Maximium daily DO concentration occurred in the early evening. These fluctations were due to daily

cycles of photosynthesis and respiration. Diurnal fluctuations decreased in the fall and winter as a result of ice cover and reduced biological activity.

The discussion of the DO results has been limited due to the lack of accuracy inherent in the results, as discussed in 'Report 2: Evaluation of the Automatic Monitors'. This lack of accuracy reduces the usefulness of the DO data. As a result, it will be difficult to assess increases in DO concentration anticipated to result from GDUP return flows.

3.5 Specific Conductance

Daily mean specific conductance at 25 C at Glen Ewen ranged from 260 us/cm to 2142 us/cm over the period of record, with a study period mean of 1213 us/cm (n = 803). At the site near Coulter, mean daily conductance ranged from 320 us/cm to 2386 us/cm, with a study period mean of 947 us/cm (n = 791).

The lower mean conductance found at Coulter is surprising. Most streams show increases in conductance with distance from source. As well, a higher proportion of winter data, which has a higher conductance, is missing from Glen Ewen than from Coulter, tending to artificially increase the mean conductance for the Coulter site. The Souris River Basin Study (1978) reported a similar finding and suggested the difference was due to the stablilizing influence of impoundments in North Dakota which capture spring runoff water, and release water through the remainder of the year when conductance in the

lower Souris River would normally be higher.

The seasonal summary statistics in Table 2 show the Coulter site to be lower in conductance than the Glen Ewen site in all seasons except spring, when conductance at Coulter was slightly higher (723 us/cm and 698 us/cm). The Souris River Basin Study (1978) reported a similar finding. It should be noted, however, that the coverage of the spring period at Glen Ewen was less complete than at Coulter, which may have influenced these statistics.

A recurrent annual trend in conductance was apparent at Coulter. The conductance reached its minimum, between 300 and 500 us/cm, in the spring, coincident with peak discharge. The magnitude of peak discharge did not appear to greatly influence the minimum conductance. In 1979 and 1980 the peak discharges were 196 m3/s and 7.43 m3/s, respectively, while the minimum conductances were 320 and 398 us/cm, respectively. Following spring peak discharge, the conductance increased gradually until late summer when it leveled off around 1000 us/cm. During the fall, the conductance decreased to about 800 us/cm. After ice formation, the conductance rose rapidly to between 1500 and 1800 us/cm. Later in winter, the conductance continued to increase but at a more gradual rate until it reached its maximum level, near 2000 us/cm, just prior to spring snow melt and the resultant increase in stream flow.

Due to the large gaps in the Glen Ewen data base during the winter and early spring runoff periods each year, analysis of yearly trends for conductance was not possible. However, the periods for which data do exist show similar trends to those seen at the Coulter site.

The Garrison Diversion Unit Project has the potential to cause significant increases in total dissolved solids concentrations in the lower Souris River. Specific conductance was monitored as a surrogate variable for total dissolved solids. Conductance changed in a linear manner each year during the summer (May through August) and early winter (November through January), allowing modelling using linear regression analysis (Table 3, Figures 5 and 6). The resultant water quality models allow an estimation of the predictive ability of the data base. At the 95 per cent confidence level, changes in conductance of 250 us/cm and 325 us/cm during the summer and early winter, respectively, would be detectable from the baselines decribed by the models. Due to the lack of daily variation (Figure 4) in the conductance data, it is believed that collection of conductance data on a weekly basis for one season will be sufficent to allow detection of change using the above model. Less frequent data collection would be required if the collection was carried out for a number of years. These changes in specific conductance correspond to changes in TDS concentration of approximately 150 mg/L and 200 mg/L, well below the increases anticipated to result from the GDUP (International Garrison Diversion Study Board, 1976b). This predictive ability of the data should be valid for most flow conditions due to the wide range in discharge encountered during the study period.

The conductance data from other seasonal periods did not facilitate modelling using linear regression analysis, due to variability from year to year. Therefore a precise determination of the predictive capacity of these periods was not possible by this method.

TABLE 3 Seasonal Regression Statistics for Specific Conductance Versus Time in the Souris River near Coulter

Time Period	Best Fit Line	No. of Points	F Value	Multiple R-Squared	St. Dev. of Regression
1978 Summer	3.32x + 742.	37.	183.6	0.840	36.9
Early Winter	7.10x + 792.	9.	52.5	0.882	33.1
1979 Summer	3.90x + 408.	76.	544.6	0.880	55.8
Early Winter	26.77x + 539.	35.	128.5	0.796	180.4
1980 Summer	3.37x + 630.	91.	136.6	0.606	95.0
Early Winter	12.23x + 936.	70.	617.5	0.901	124.4
1981 Summer	2.62x + 732.	106.	264.3	0.718	56.9
Early Winter	16.04x + 861.	29.	159.2	0.855	67.9
1982 Summer	3.80x + 701.	55.	80.9	0.60	55.1
Overall					
Summer	2.79x + 663.	365.	240.5	0.40	122.4
Early Winter	13.54x + 867.	143.	753.8	0.84	164.3

Summer is May 1 to August 31.
Early Winter is November 1 to January 31.

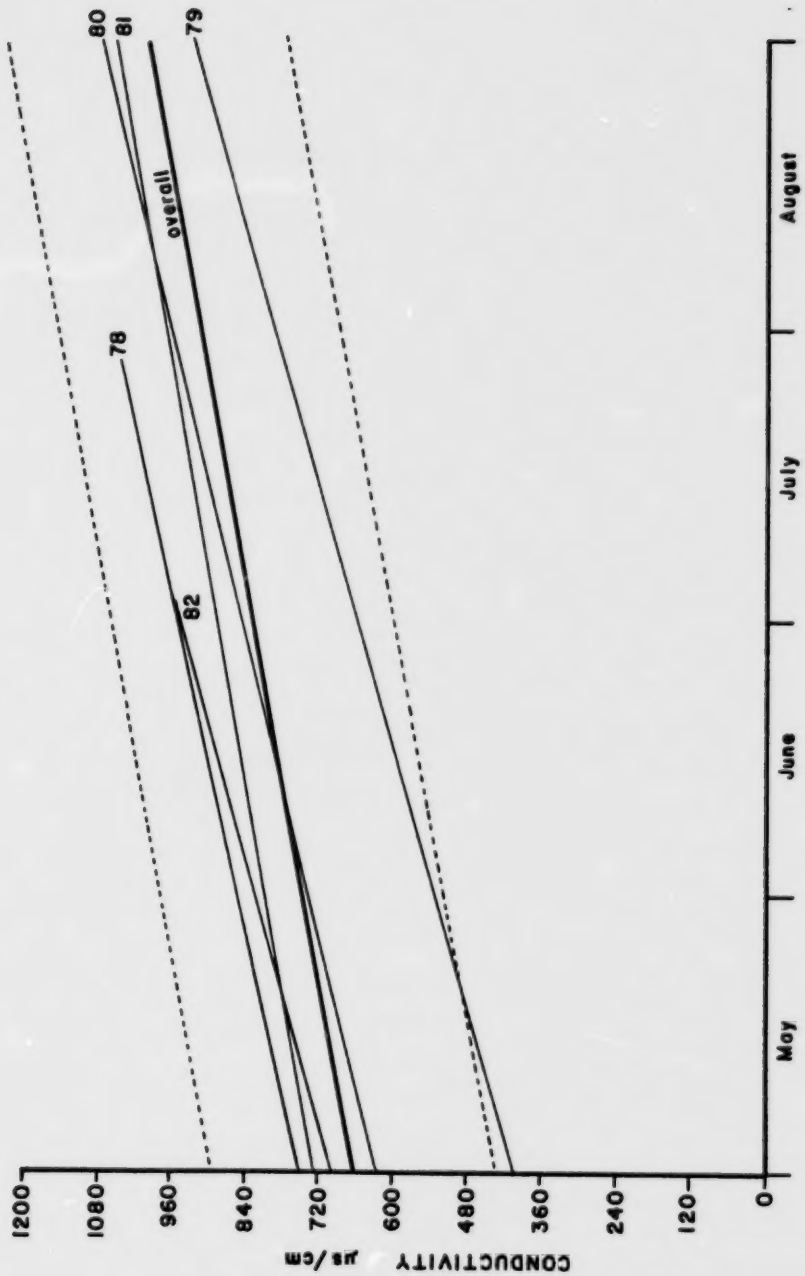

Figure 5. Annual and Overall Regression Lines for Specific Conductance at Coulter during Summer with 95 per cent Confidence Interval for the Overall Line.

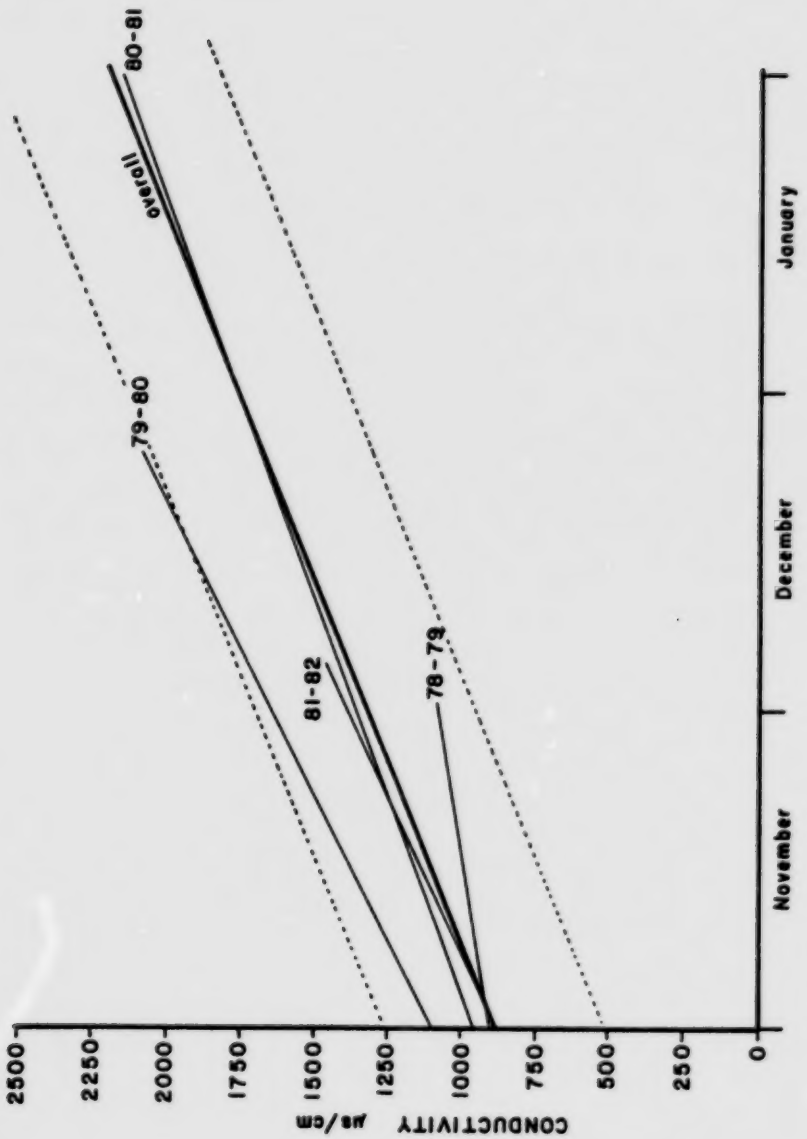

Figure 6. Annual and Overall Regression Lines for Specific Conductance at Coulter during Early Winter with 95 per cent Confidence Interval for the Overall Line.

4.0 SUMMARY AND CONCLUSIONS

The automatic monitoring program conducted from 1977 to 1982 at two sites on the Souris River produced a number of findings:

- conductance tended to be lower at Coulter than at Glen Ewen during all seasons except spring;

- reproducible annual trends in conductance occurred each year at the Coulter site;

- pH was typically higher at the Coulter site;

- lowest pH occurred annually during the winter months at both sites;

- recurrent periods of dissolved oxygen decline occurred at Coulter during the summer and winter months.

- wide diurnal fluctuations in dissolved oxygen, as high as 8 mg/L, occurred during the summer months at both sites.

The International Garrison Diversion Study Board identified a number of potential effects the GDUP could have on the water quality of the lower Souris River. The objective of this study was to provide continuous water quality data for use in describing baseline conditions during the pre-irrigation period, to be used in quanitifying some of these effects should the GDUP become reality.

A major effect of GDUP irrigation return flows is expected to be increased total dissolved solids concentration in the lower Souris River. Regression analysis of the auto-monitoring specific conductance data produced simple water quality models for two periods of the year. At 95 per cent confidence, the model for May through August will detect a change in TDS concentration of 150 mg/L. The model for November through January will detect a change of 200 mg/L. These models will therefore be capable of detecting the changes in TDS concentration predicted to be caused by return flows from GDUP.The data from the other periods of the year did not lend themselves to linear regression modelling. Therefore a determination of the data's predictive capacity for these periods was not possible by this method.

A second potential effect of GDUP will be to increase the dissolved oxygen concentration in the lower Souris River. This increase is expected to be most significant during the winter, the period for which auto-monitoring data is most limited. Comparison of auto-monitoring data with monthly manual measurements showed the auto-monitoring DO data to be of insufficent accuracy for use in confidently describing baseline conditions.

Water temperature and pH in the lower Souris River in Canada are not expected to be significantly influenced by irrigation return flows from the Garrison Diversion Unit Project.

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Water Quality Branch, 1984b. Detailed Surface Water Quality Data. Saskatchewan 1980-1981. Inland Waters Directorate,Western and Northern Region, Regina, Saskatchewan.

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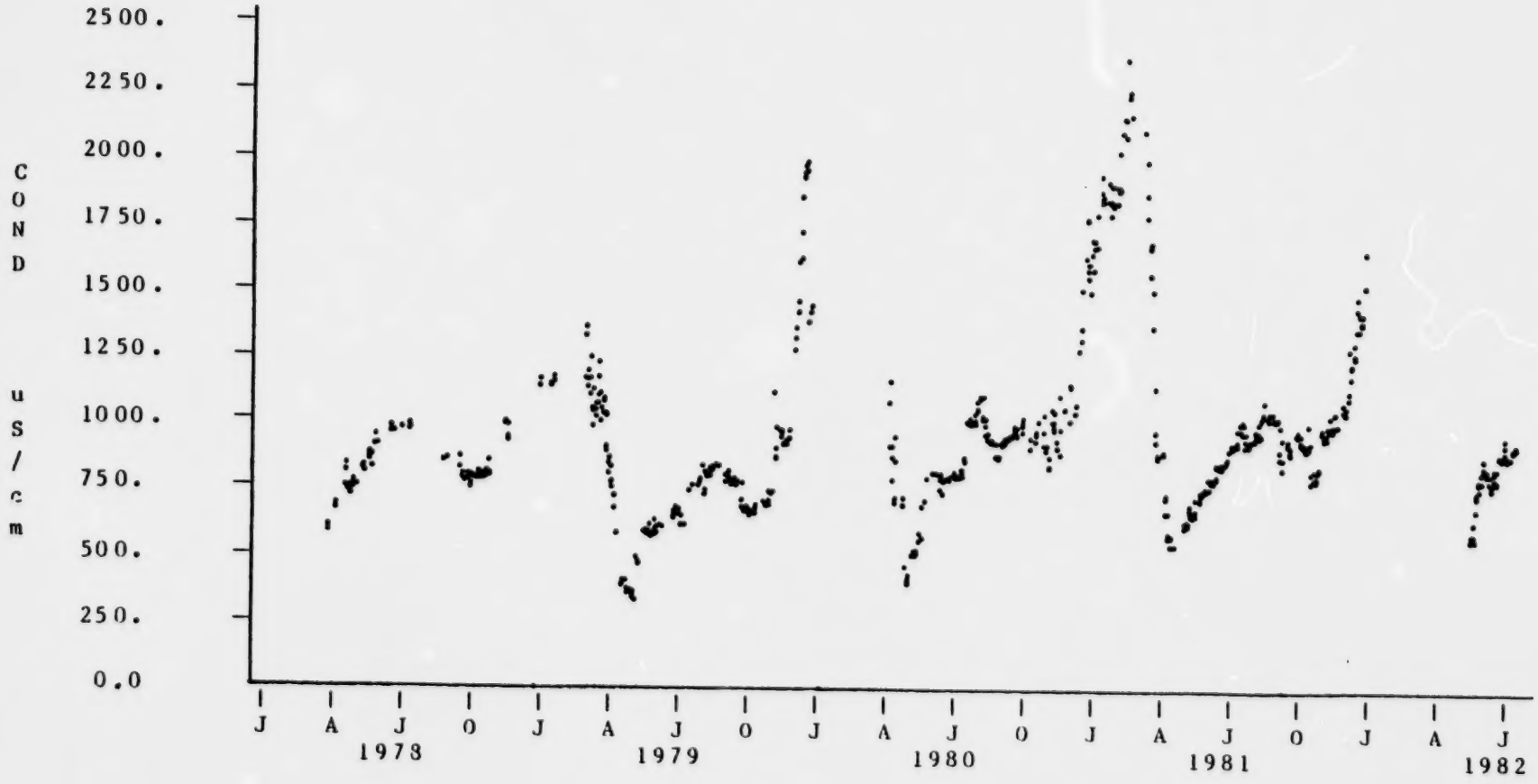

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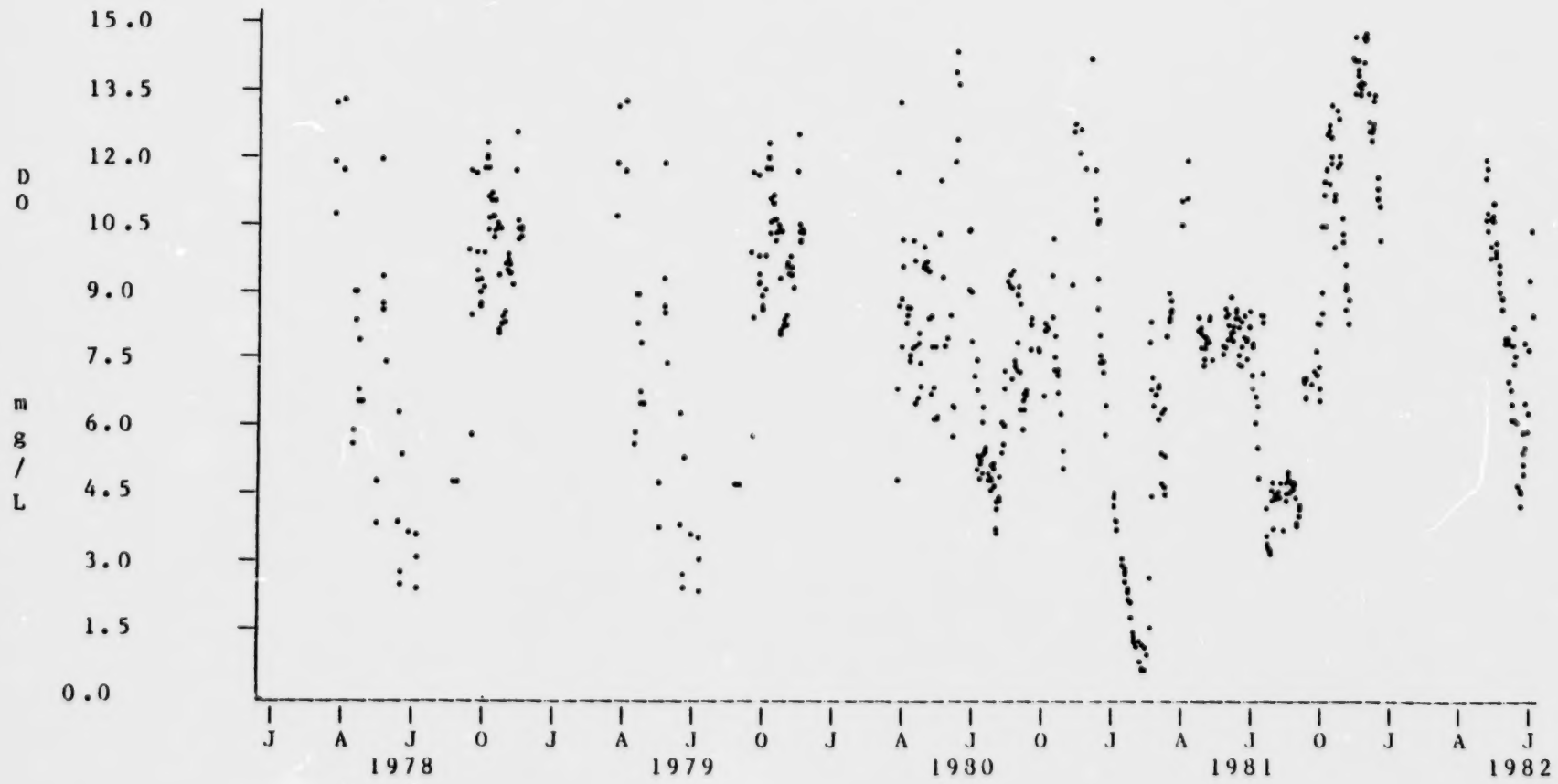
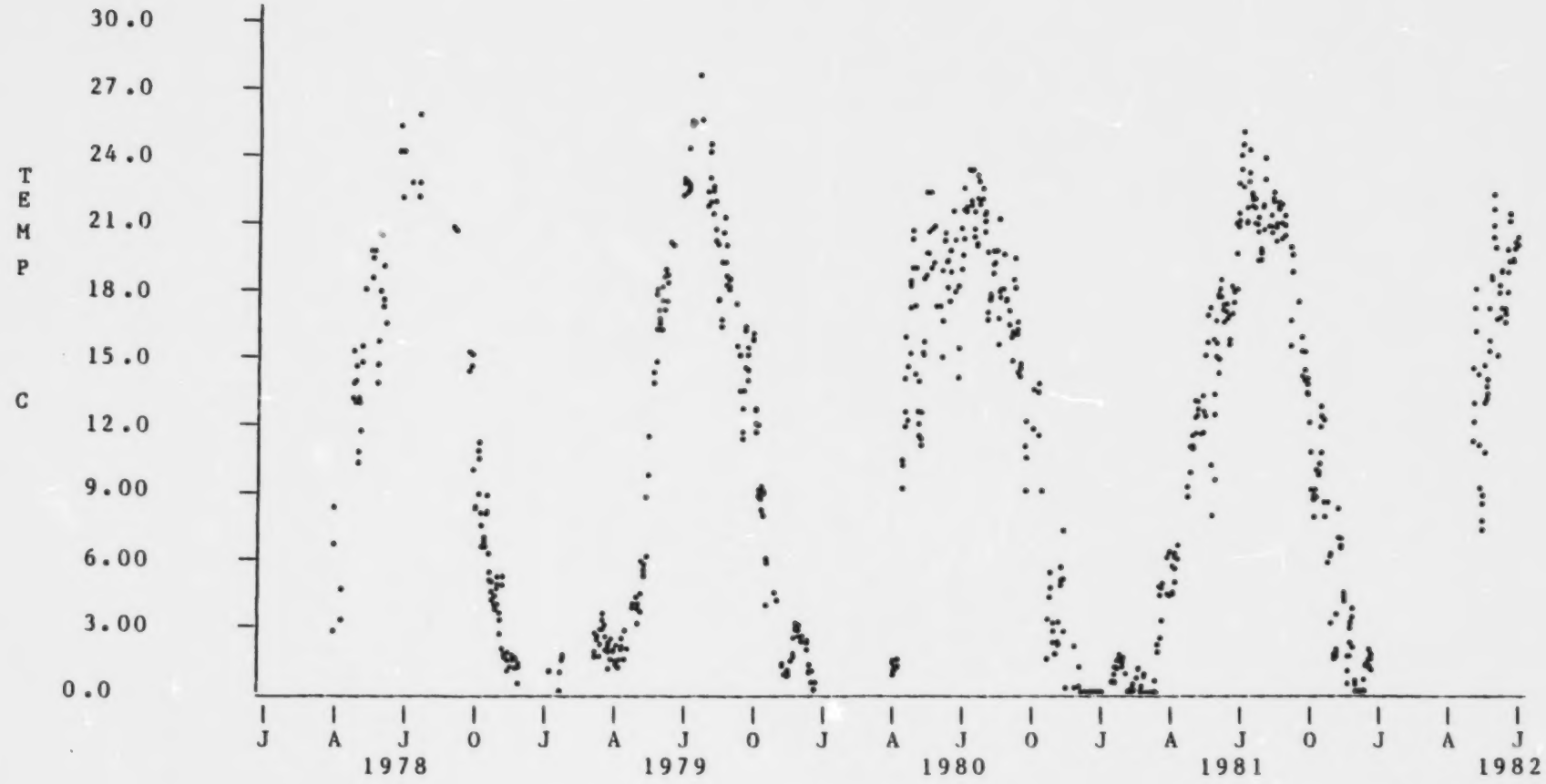


Figure 2.Dissolved Oxygen in the Souris River near Coulter,1978 to 1982.



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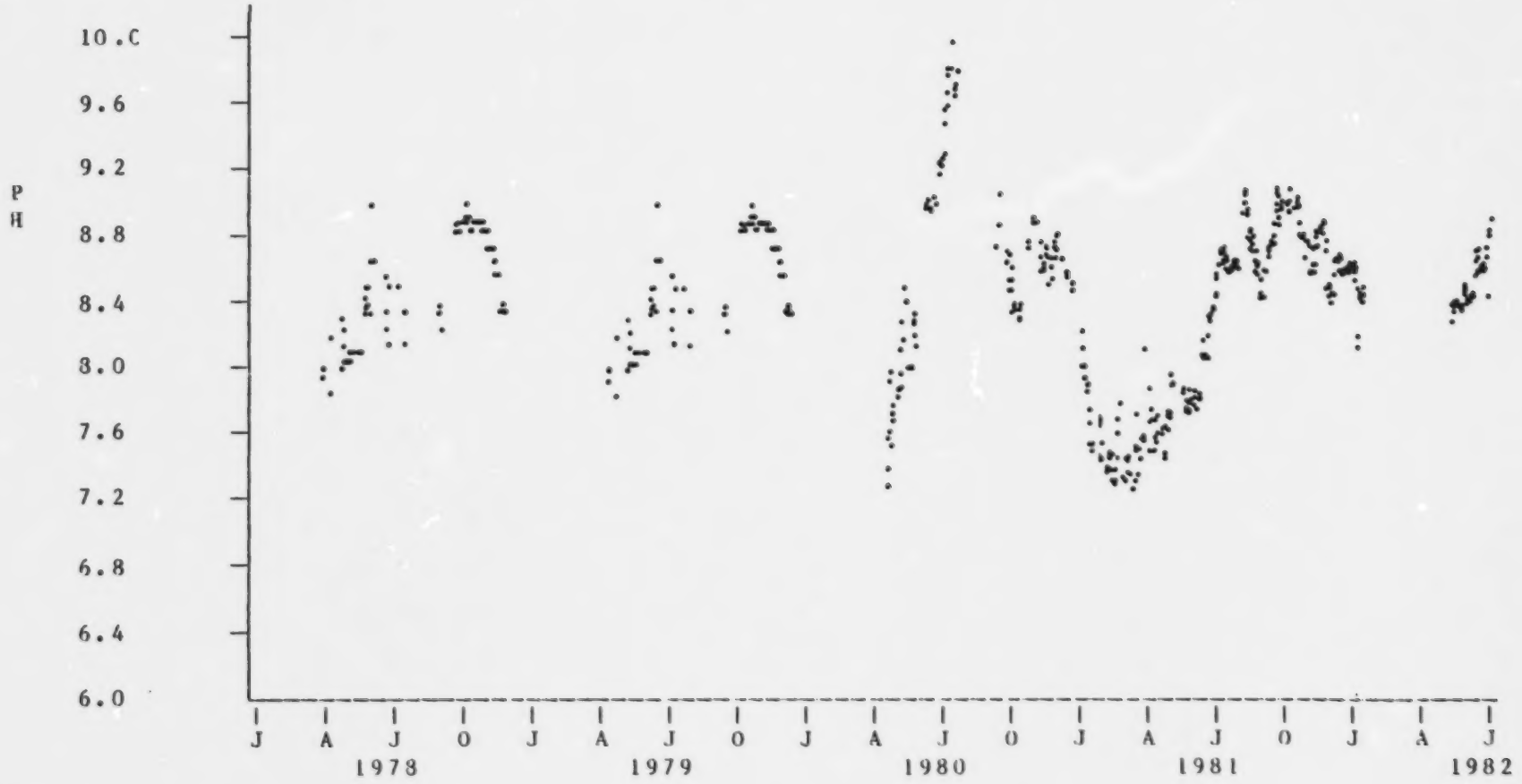

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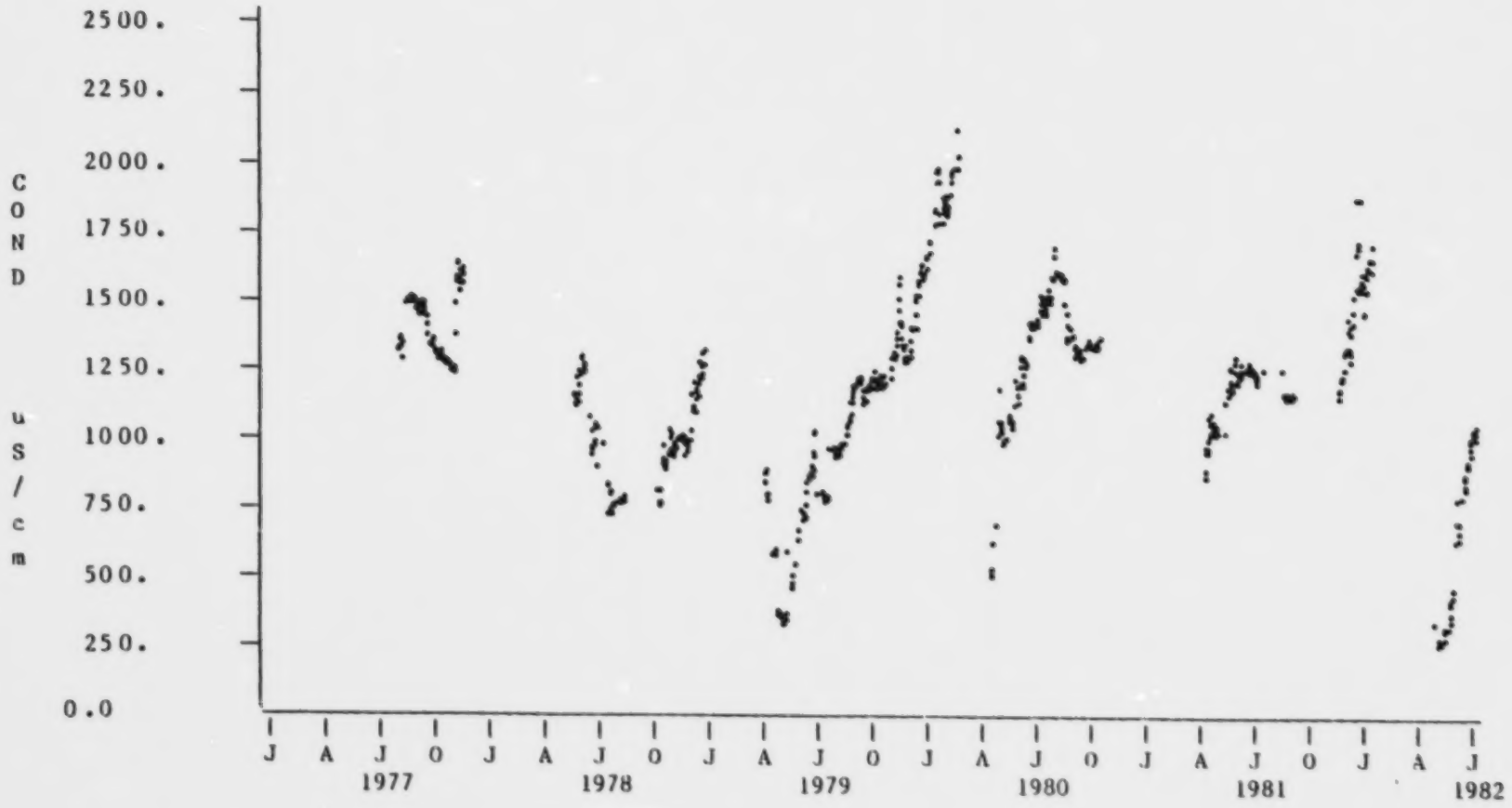
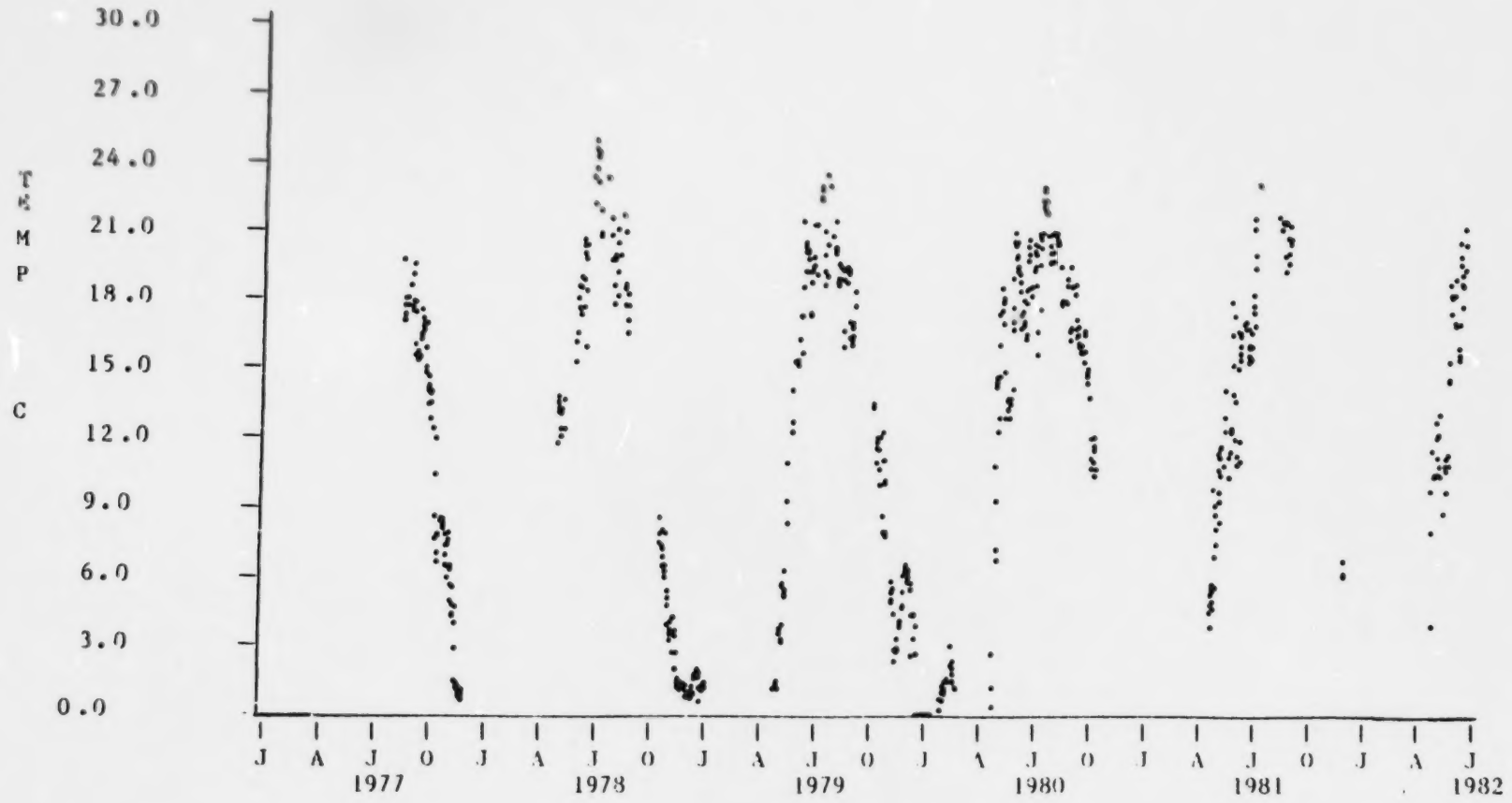


Figure 5.Conductivity in the Souris River near Glen Ewen,1977 to 1982.



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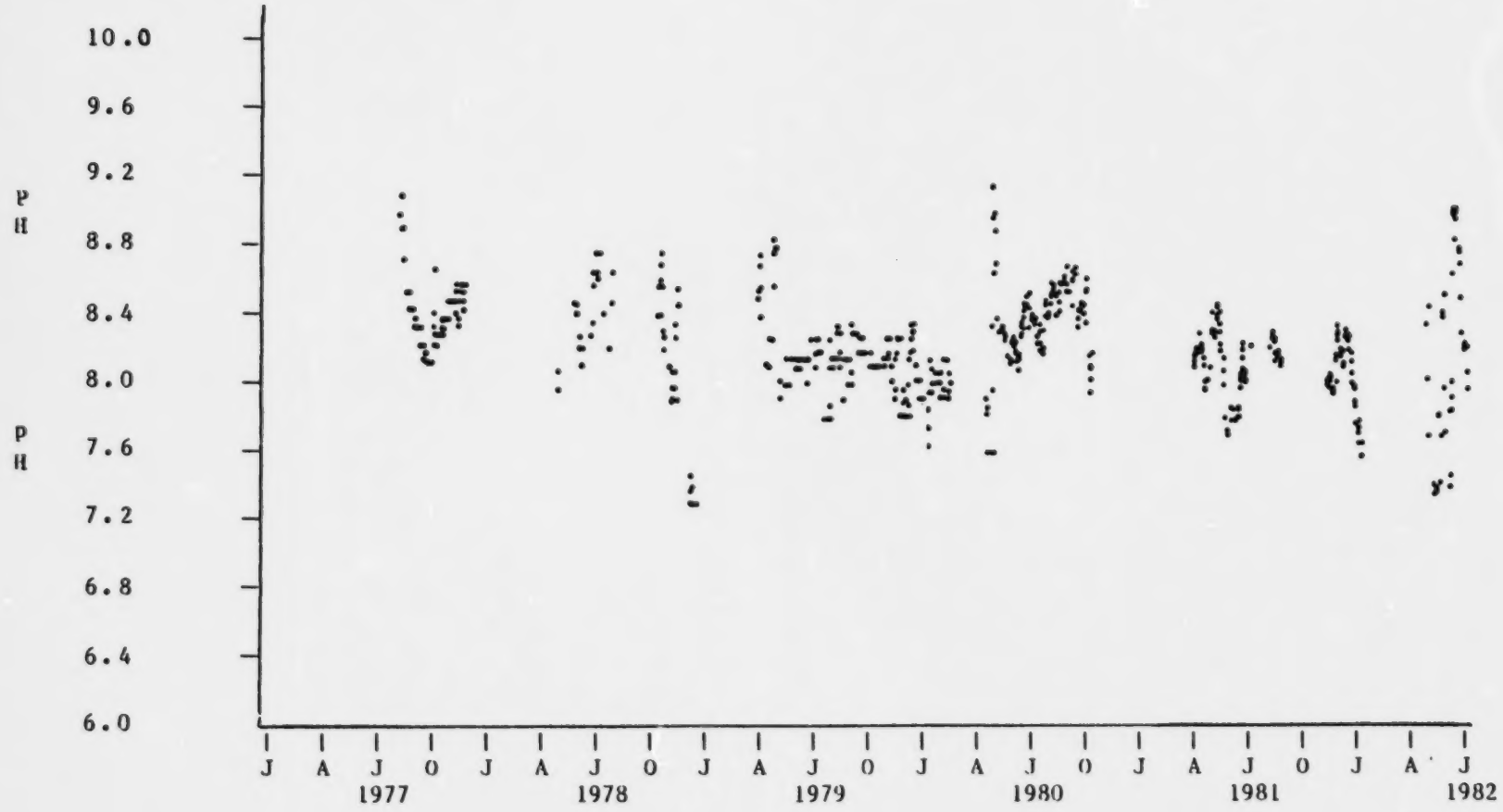

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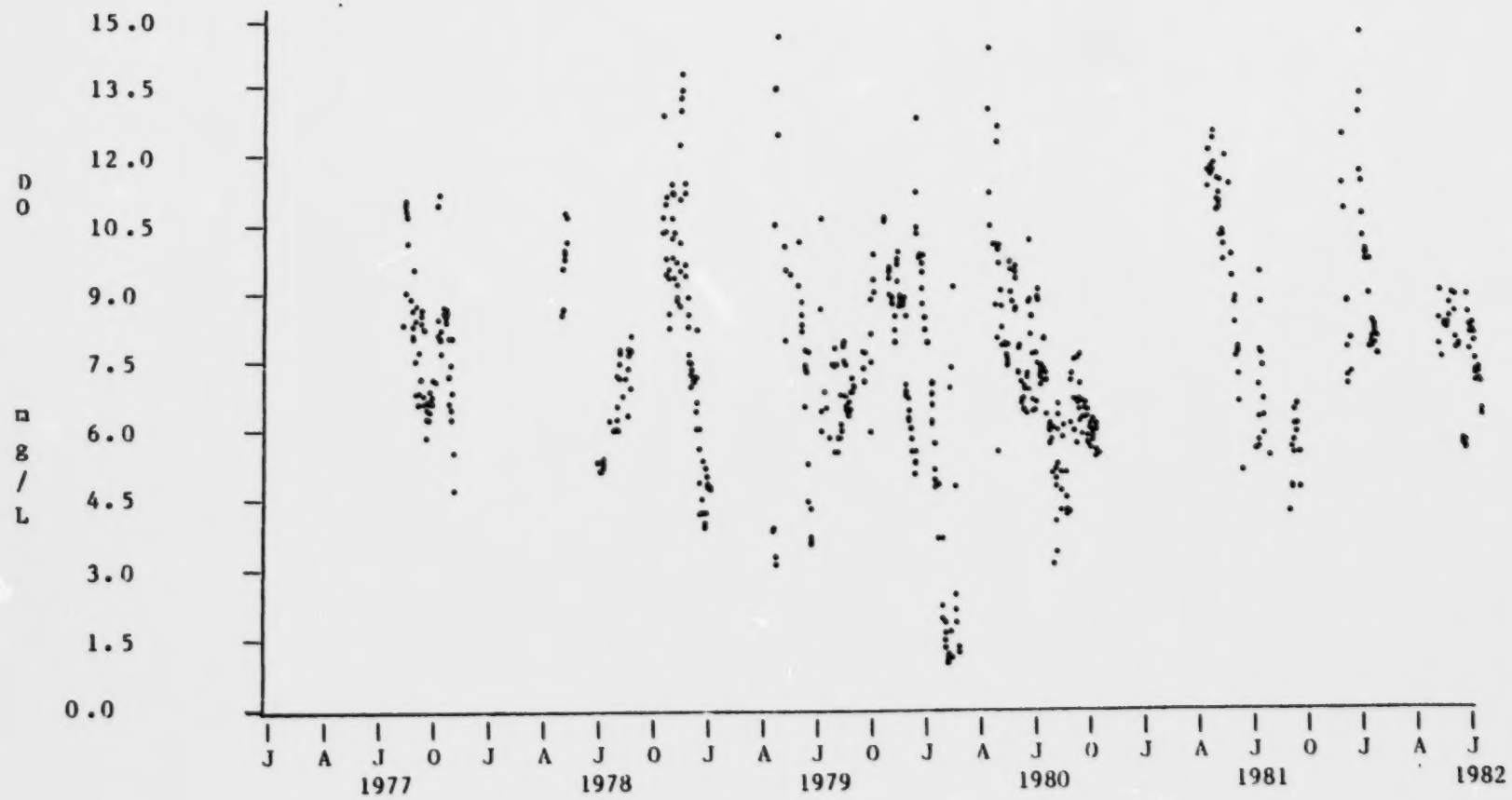

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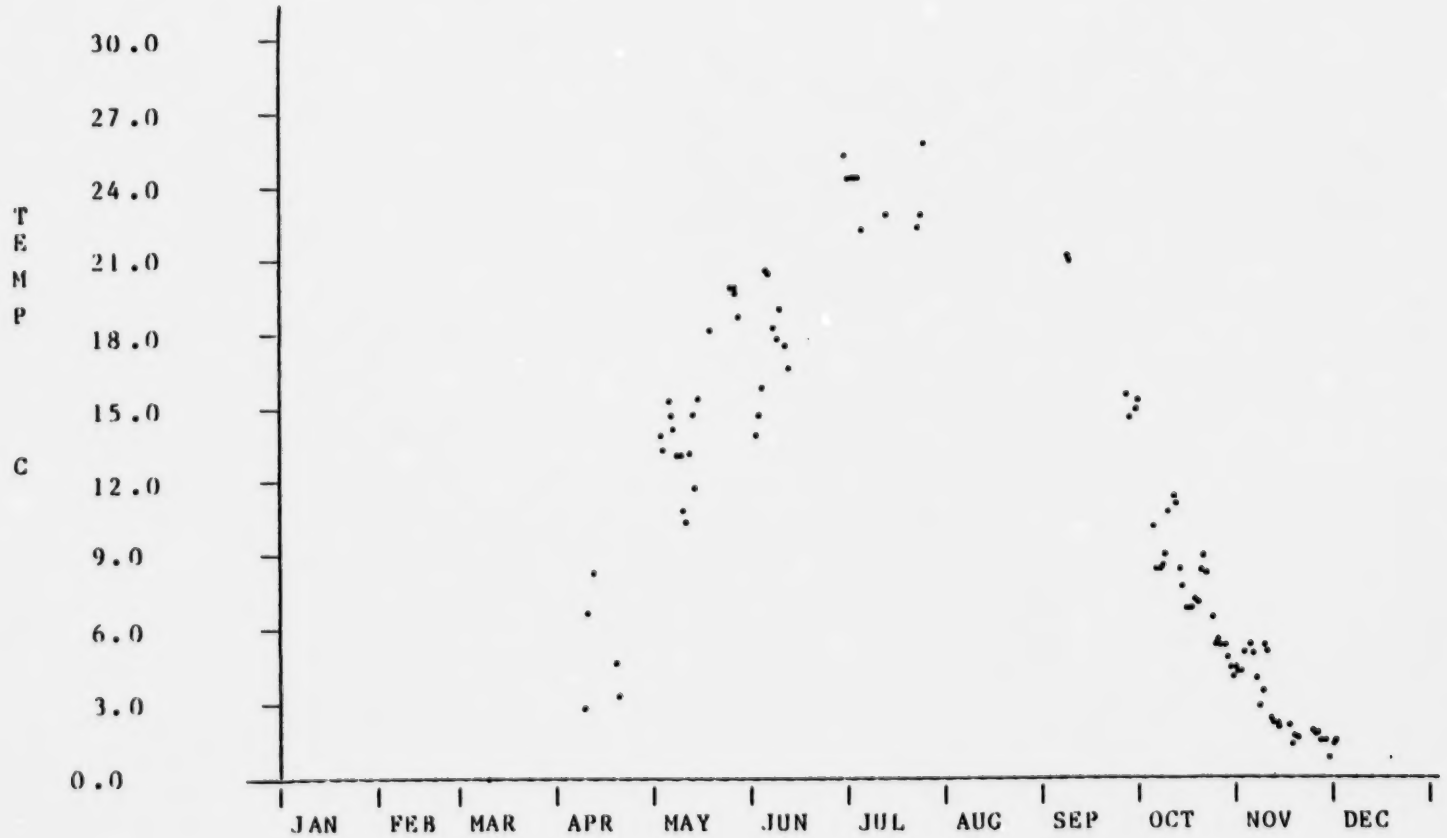
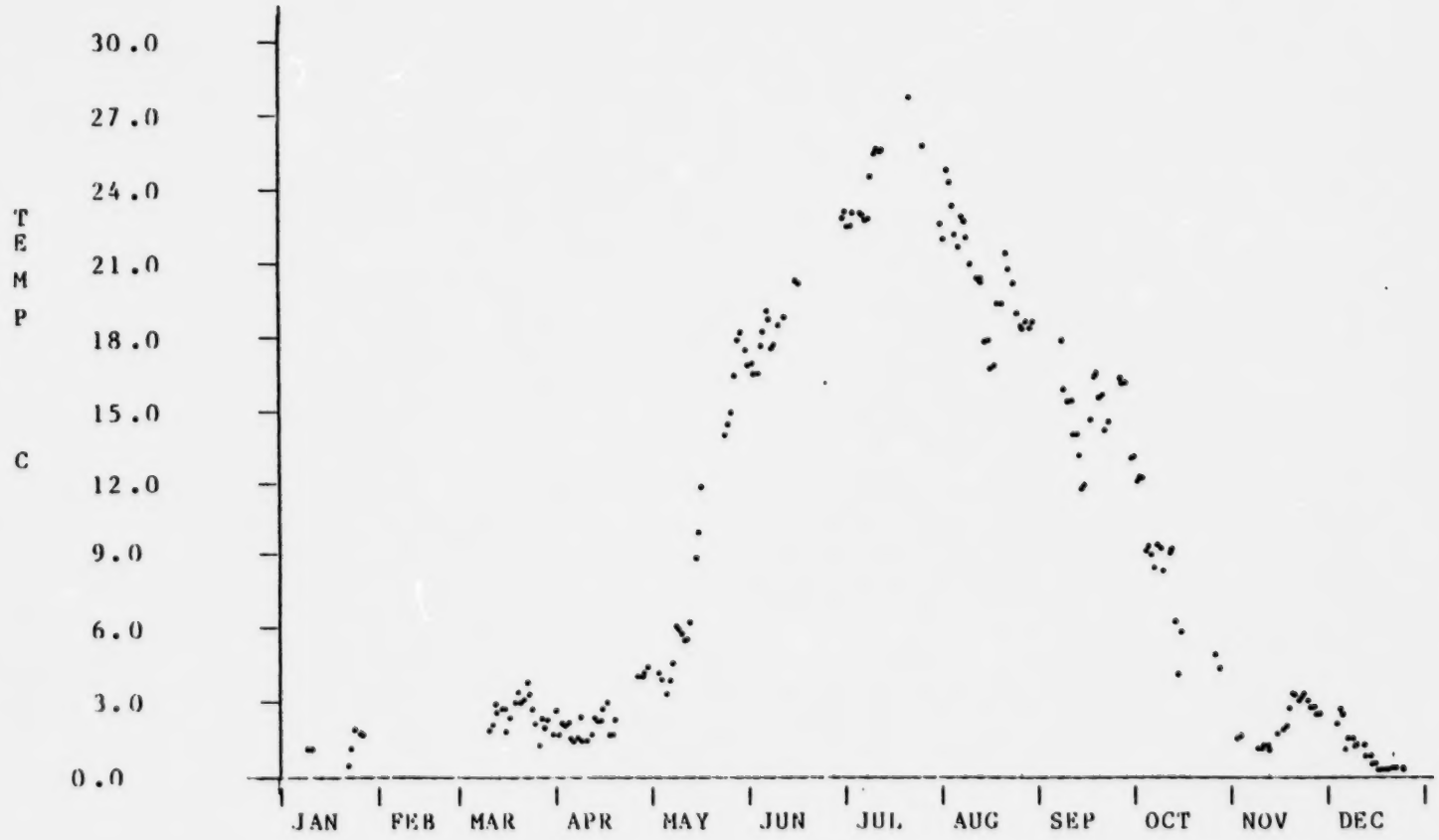


Figure 1. Mean Daily Temperature in the Souris River near Coulter during 1978.



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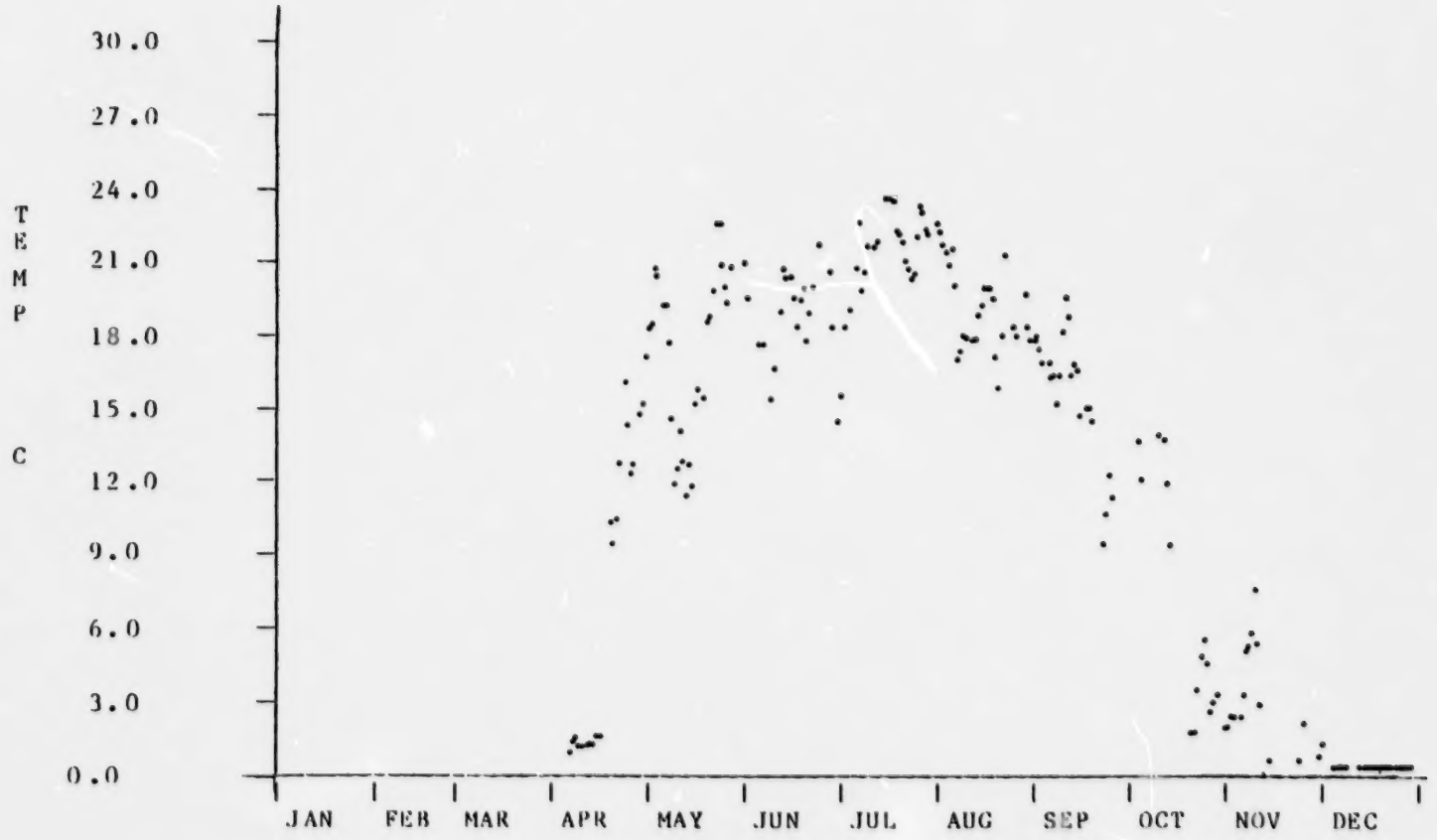

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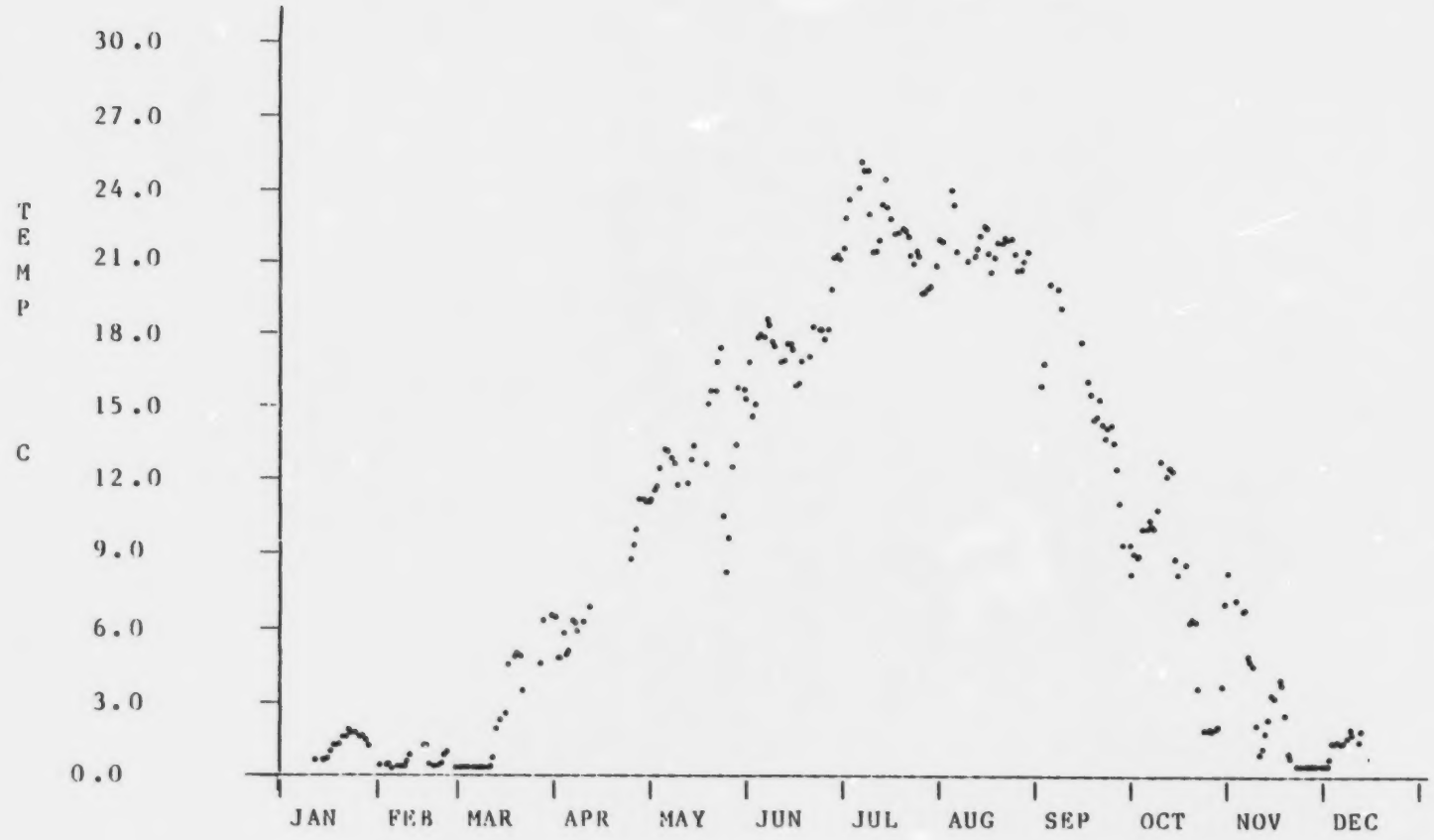
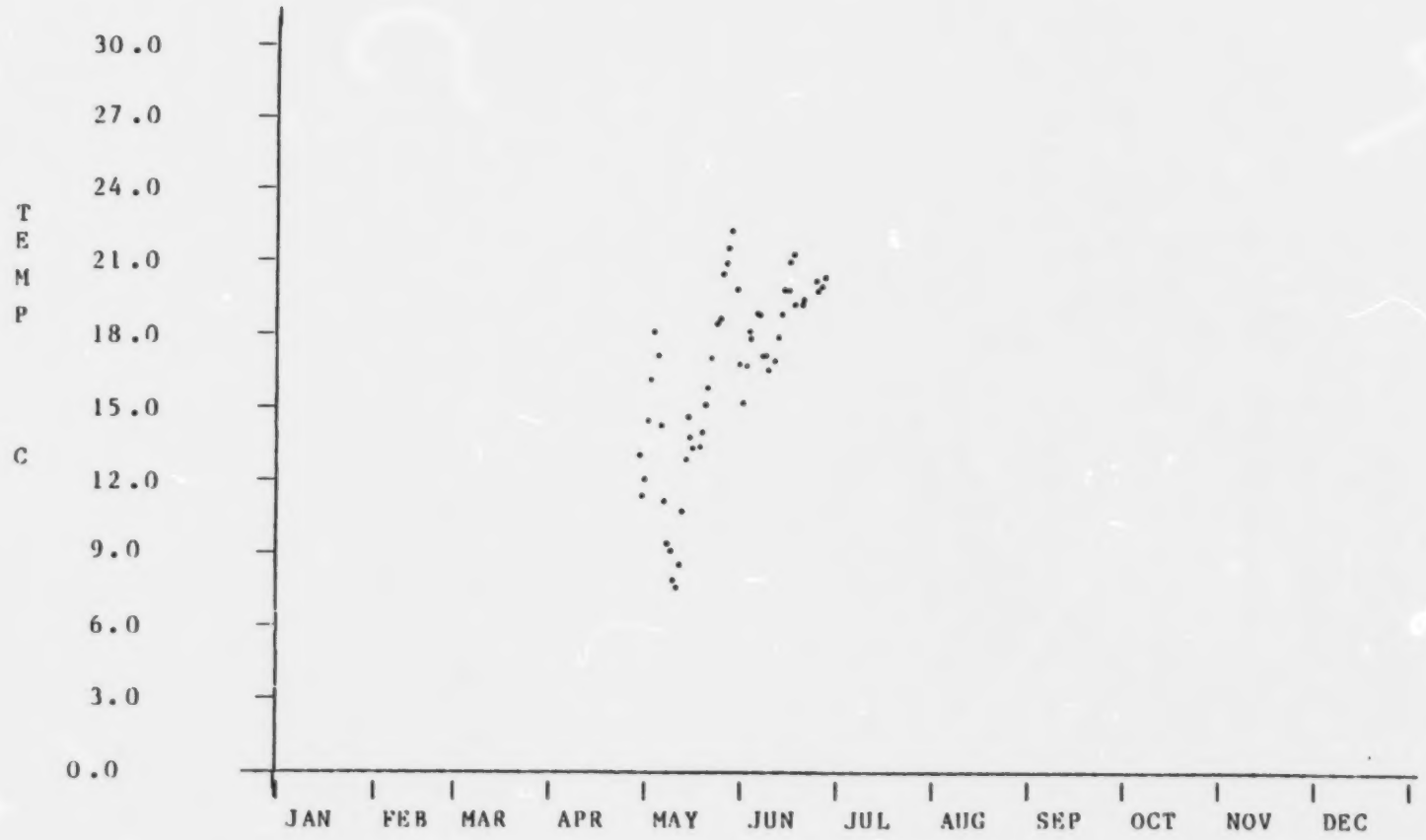


Figure 4. Mean Daily Temperature in the Souris River near Coulter during 1981.



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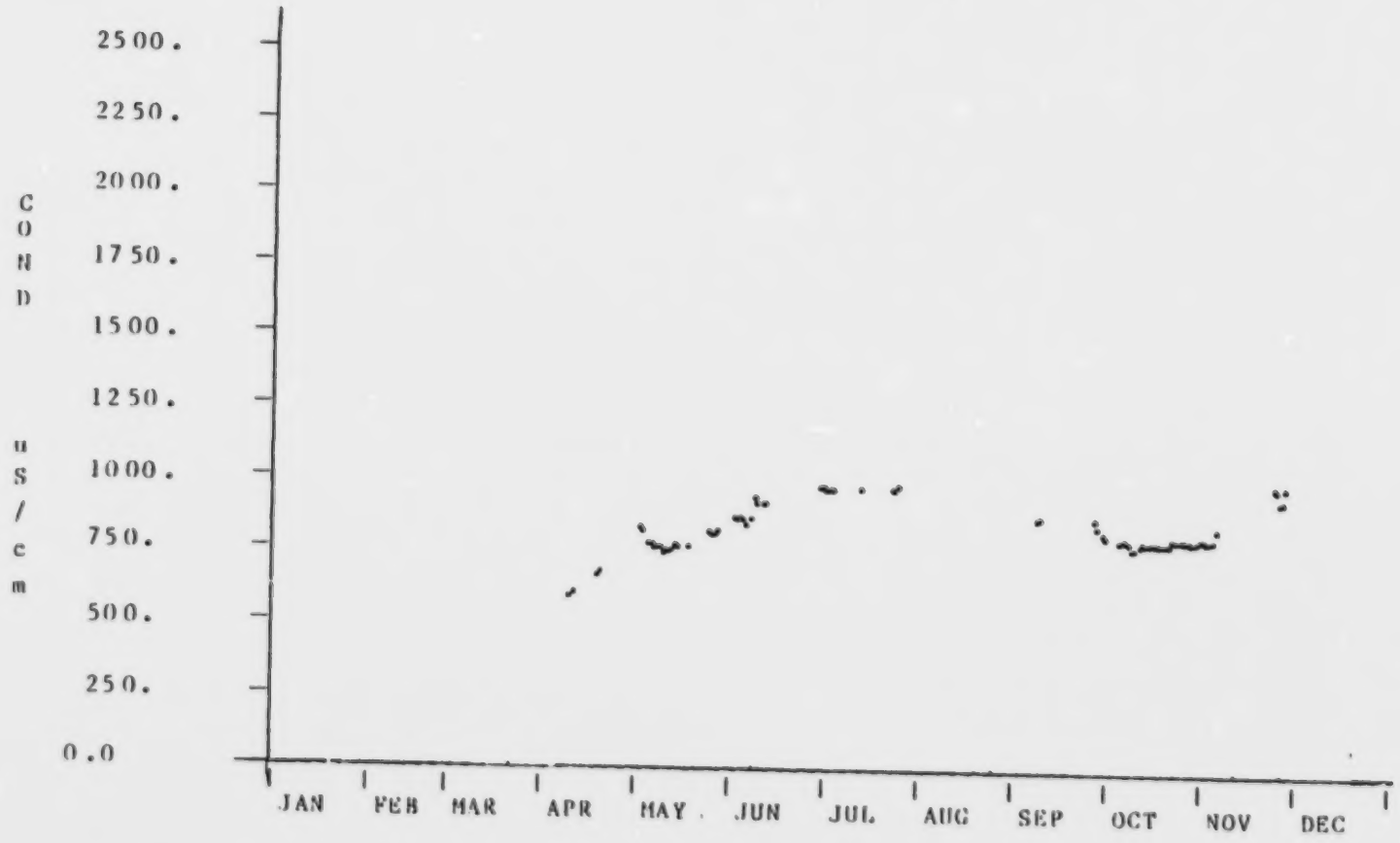


Figure 6. Mean Daily Conductivity in the Souris River near Coulter during 1978.

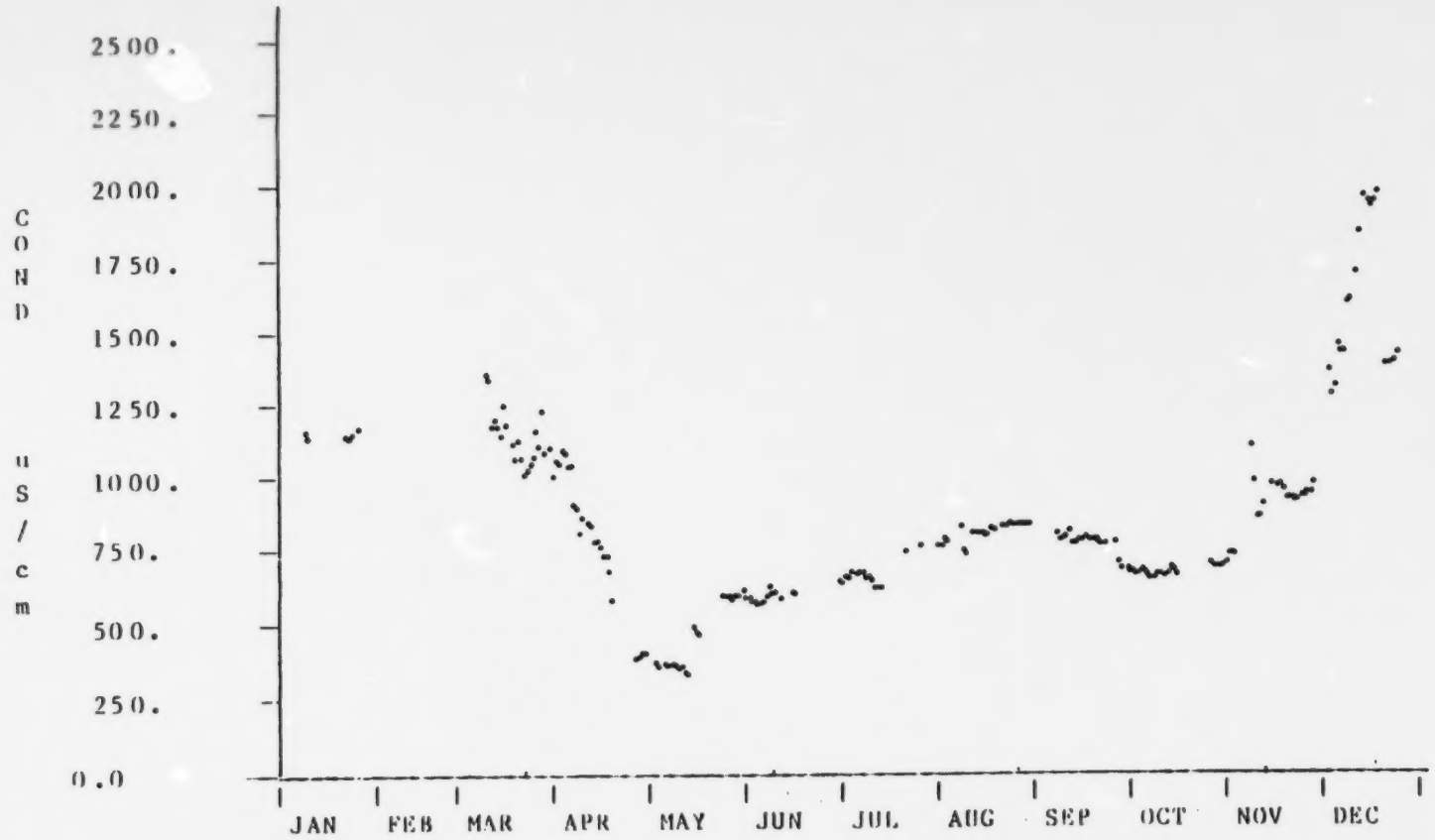


Figure 7. Mean Daily Conductivity in the Souris River near Coulter during 1979.

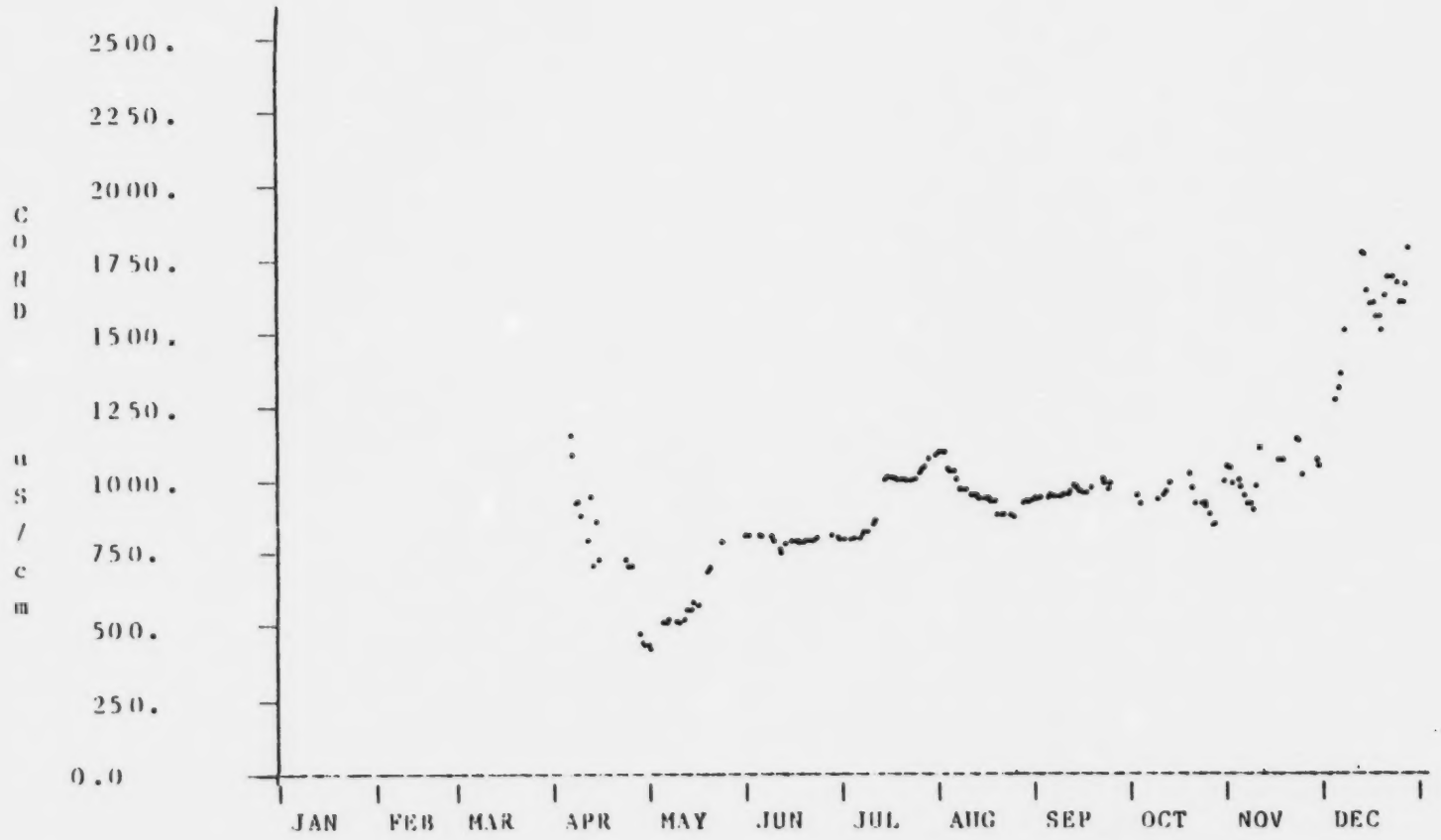


Figure 8. Mean Daily Conductivity in the Souris River near Coulter during 1980.

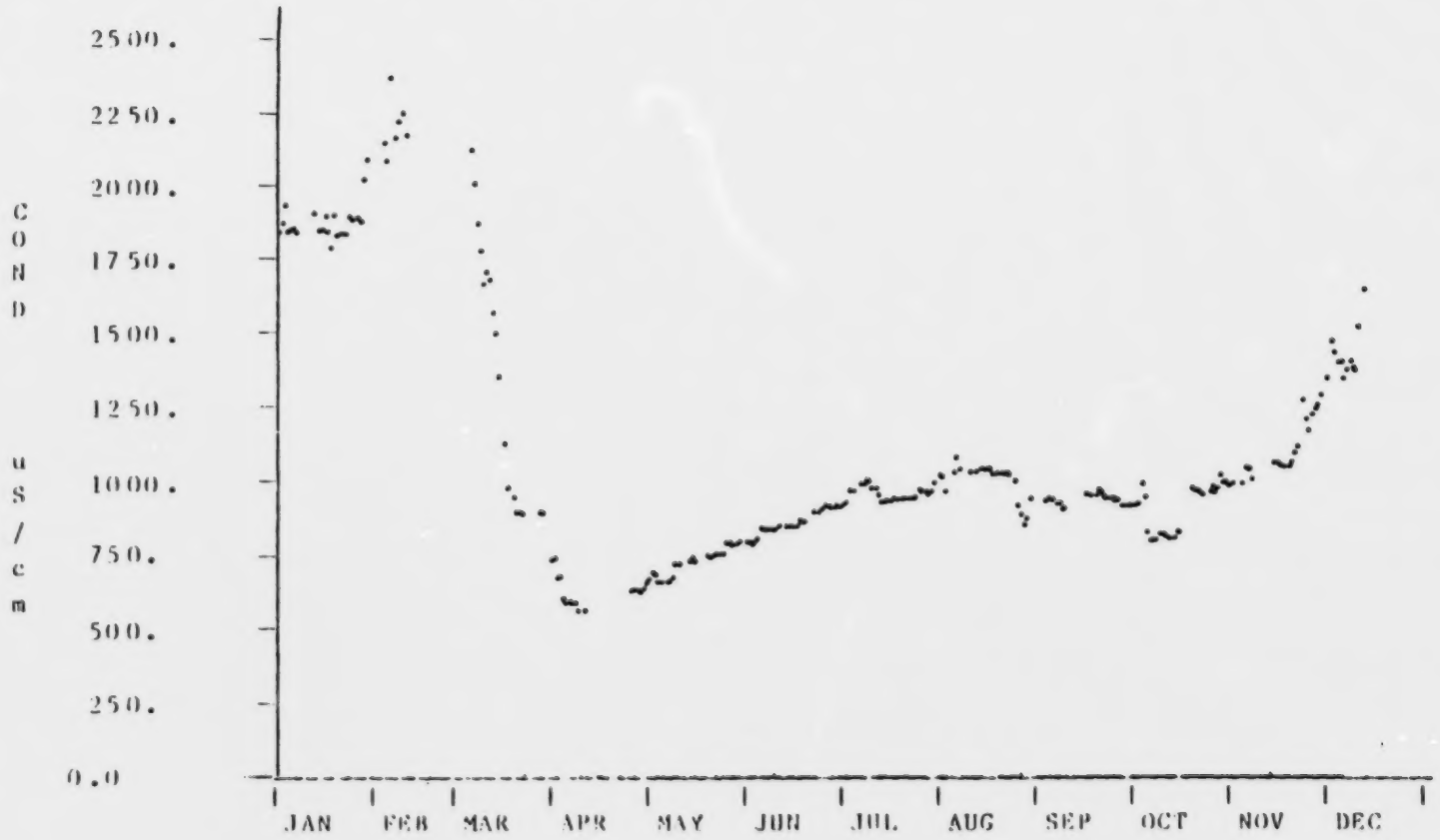
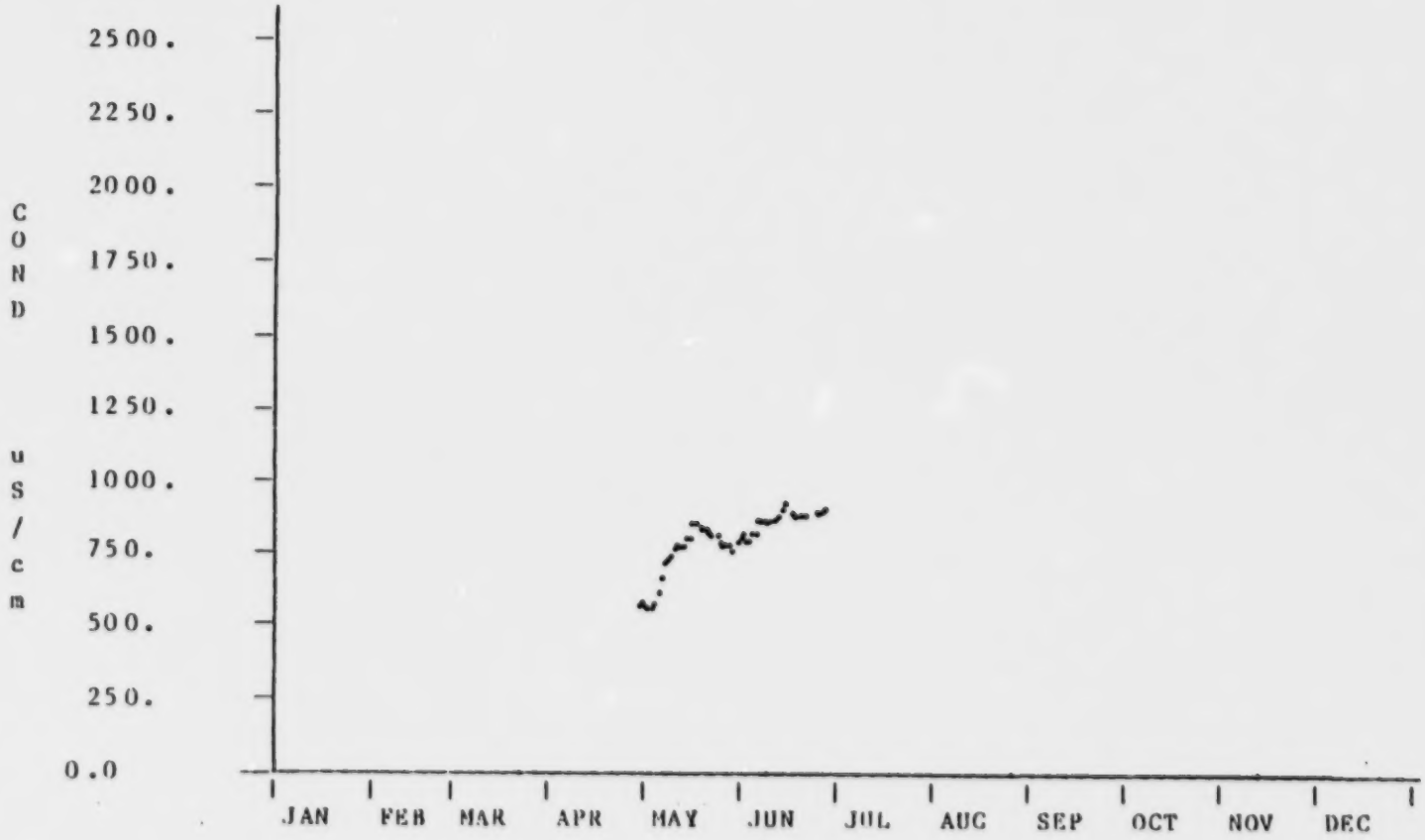


Figure 9. Mean Daily Conductivity in the Souris River near Coulter during 1981.



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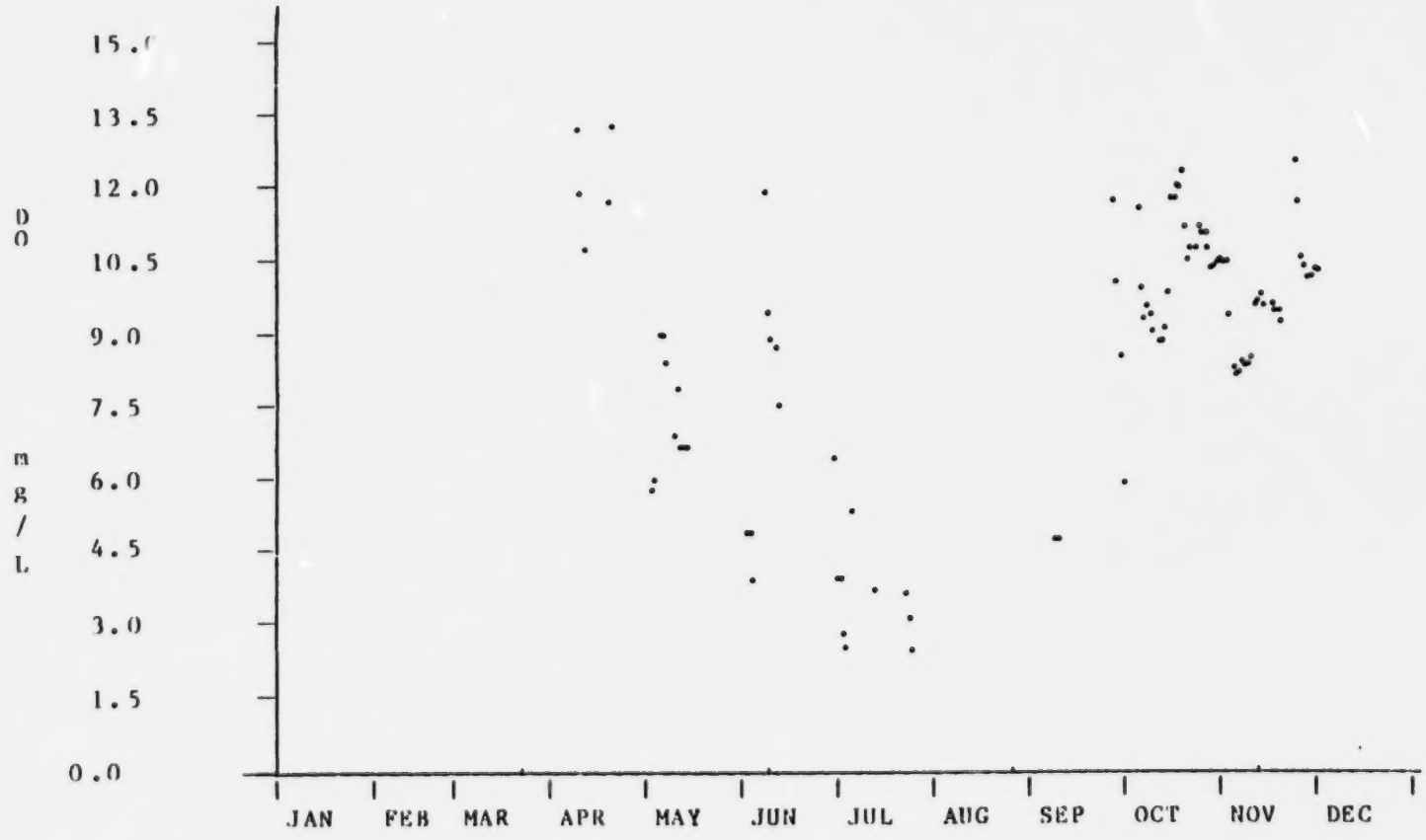
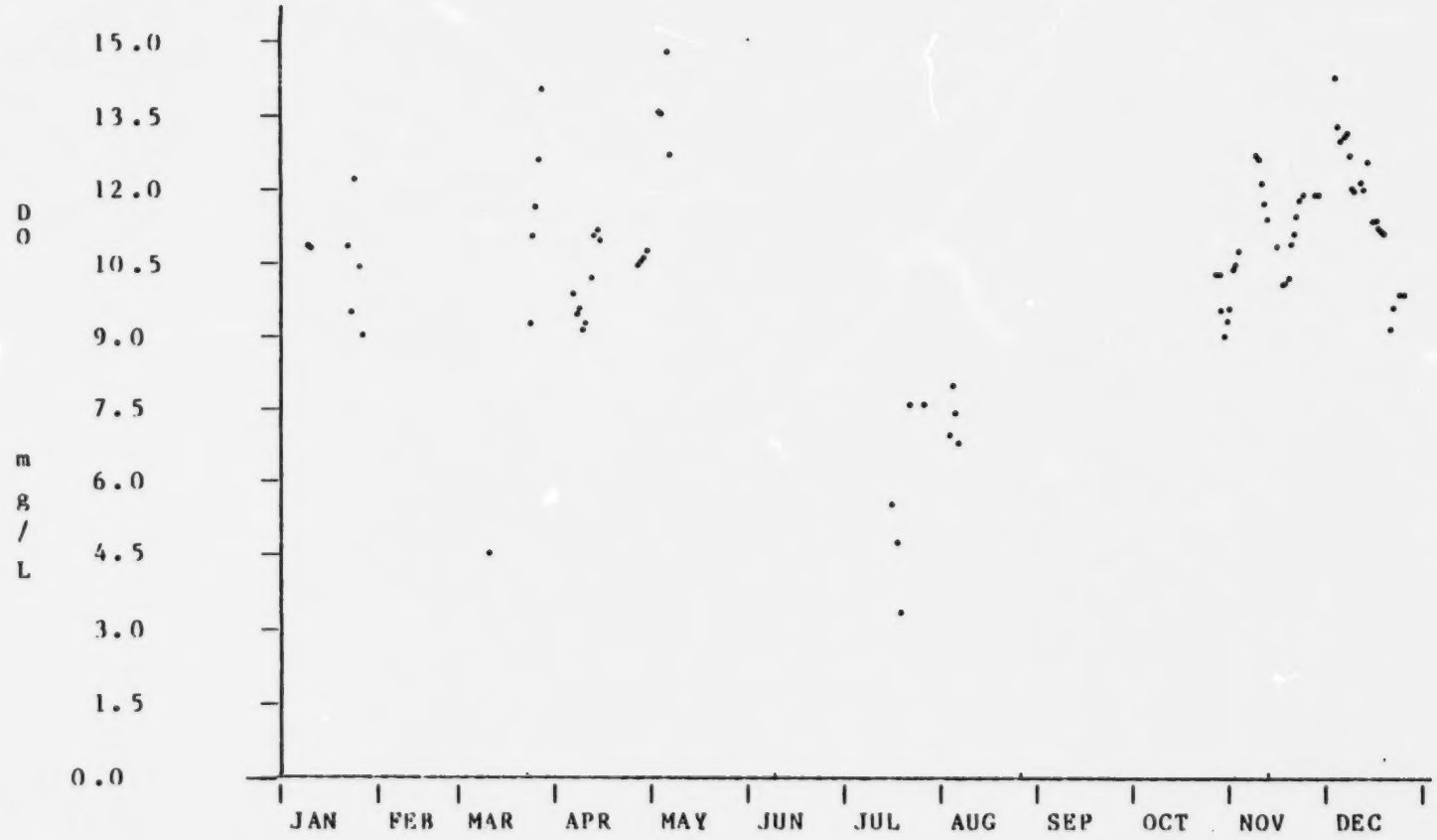


Figure 11. Mean Daily Dissolved Oxygen in the Souris River near Coulter during 1978.



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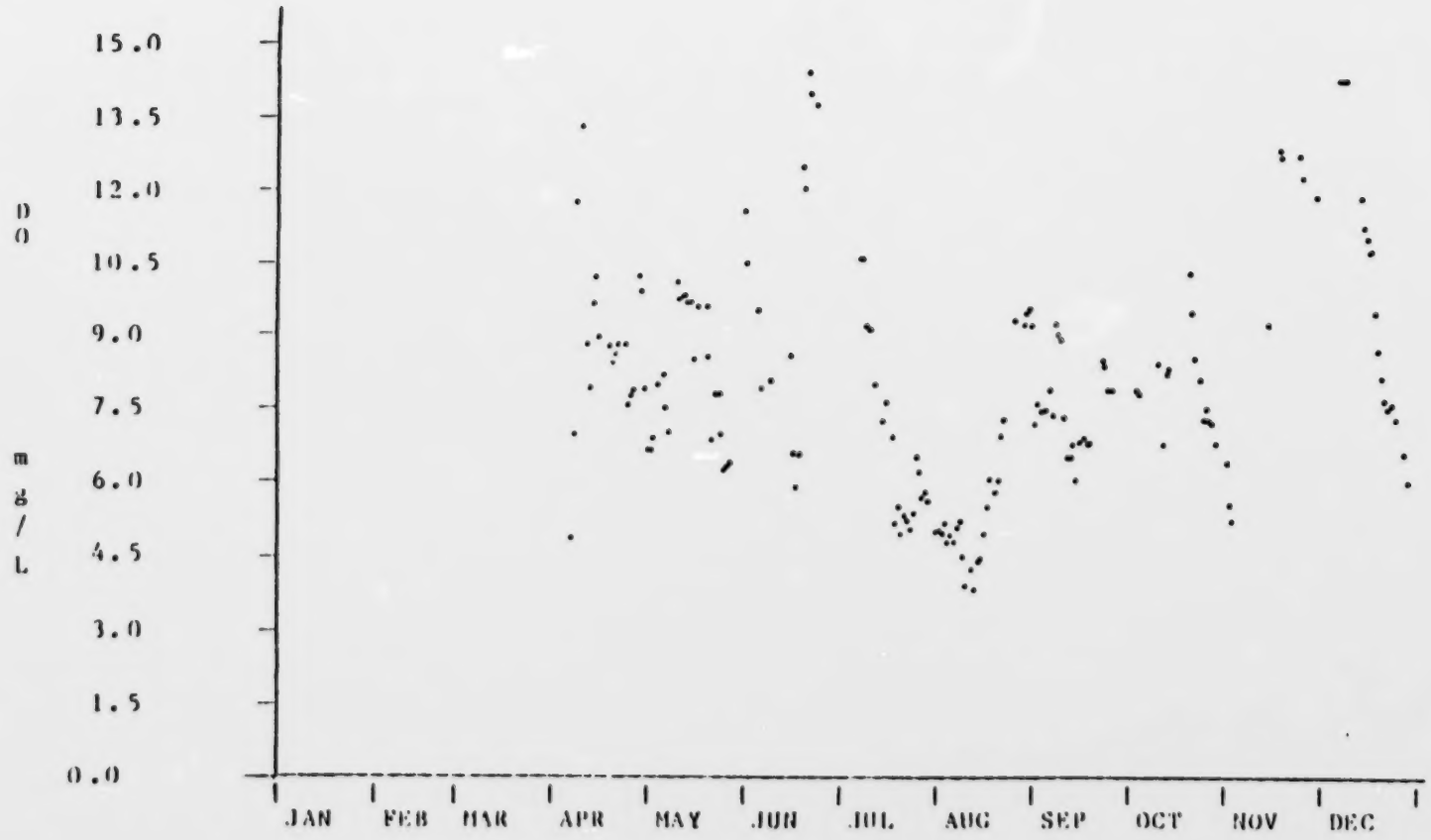

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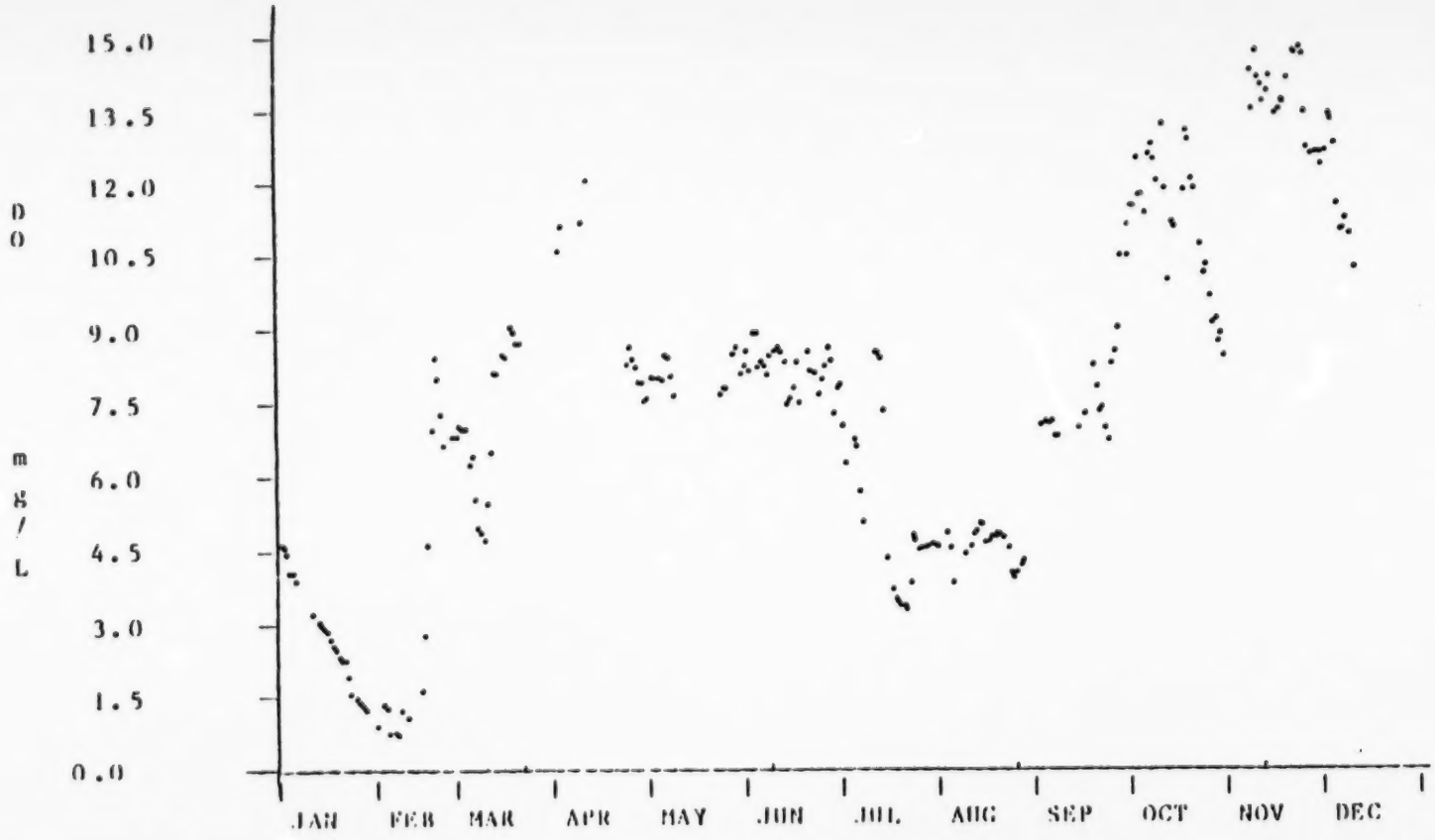

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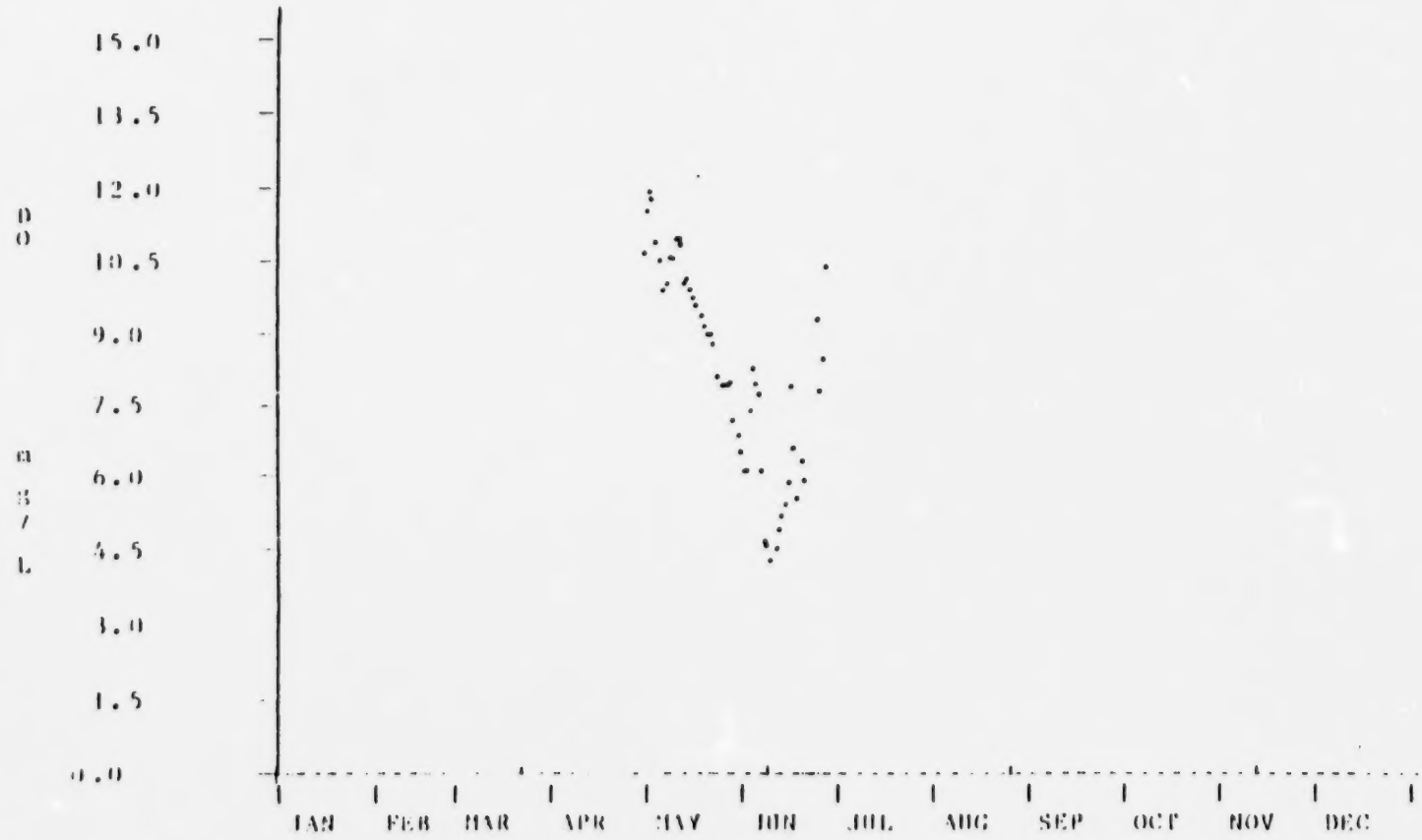

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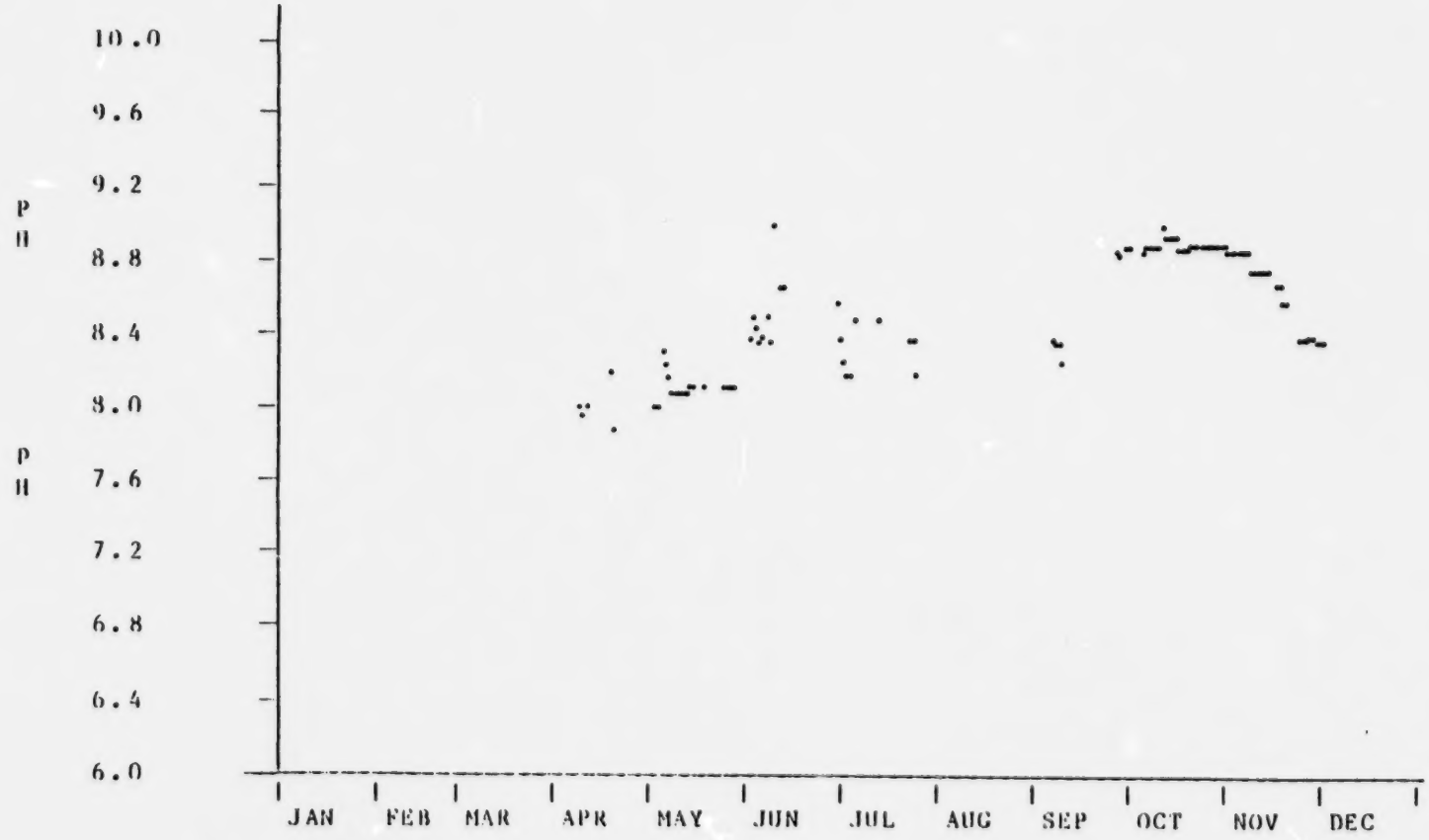
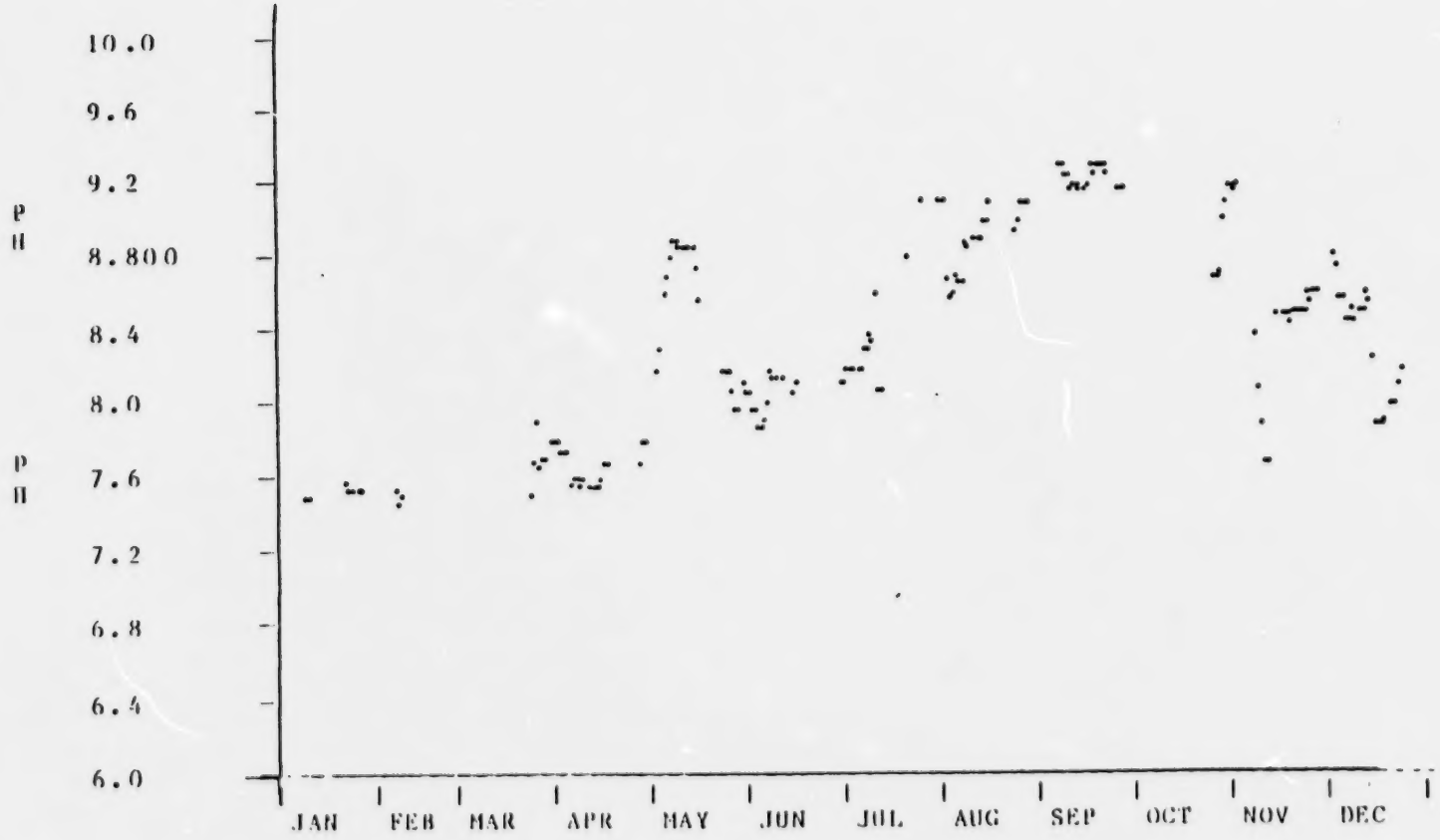


Figure 16. Mean Daily pH in the Souris River near Coulter during 1978.



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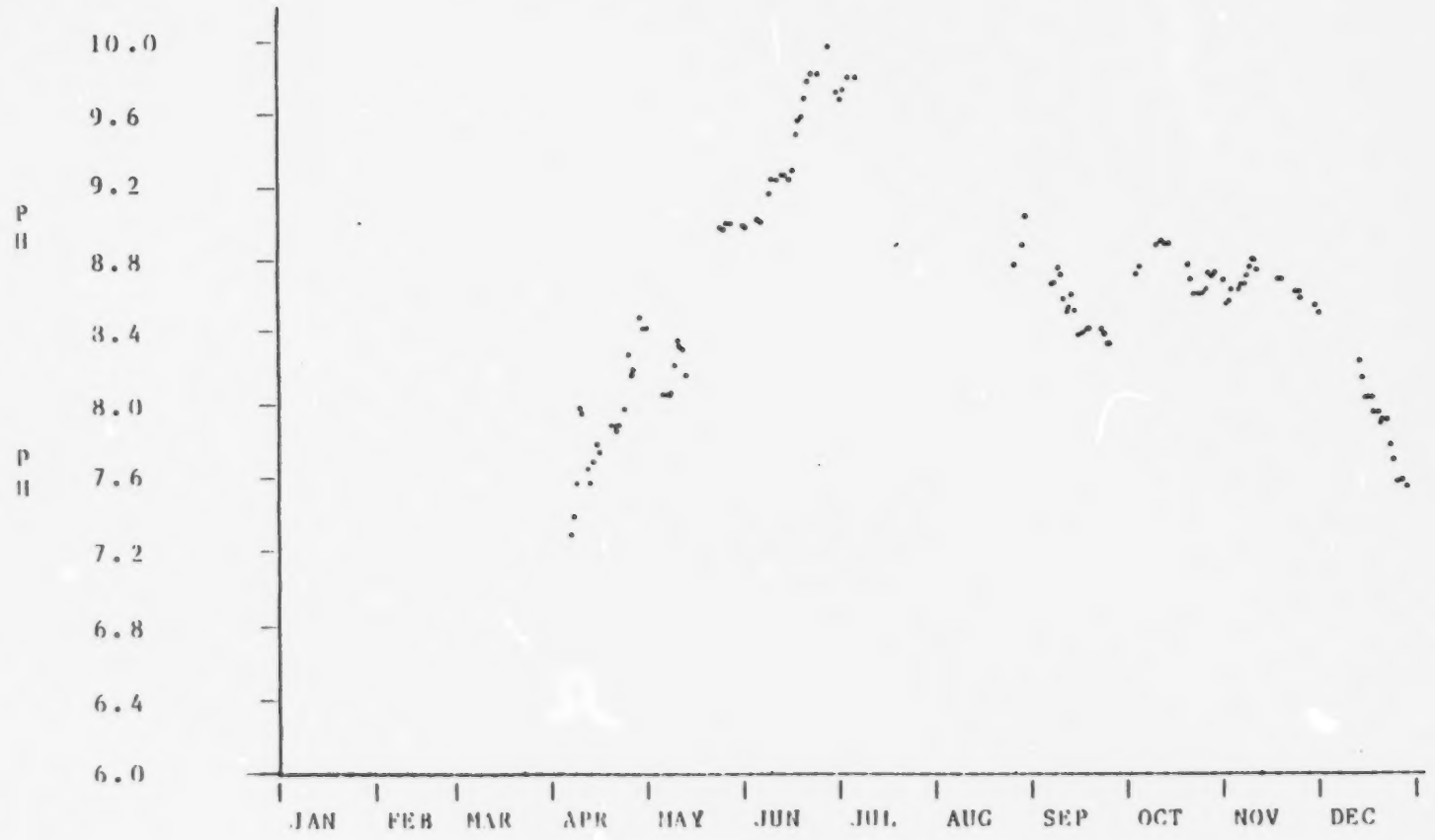

Figure 18. Mean Daily pH in the Souris River near Coulter during 1980.

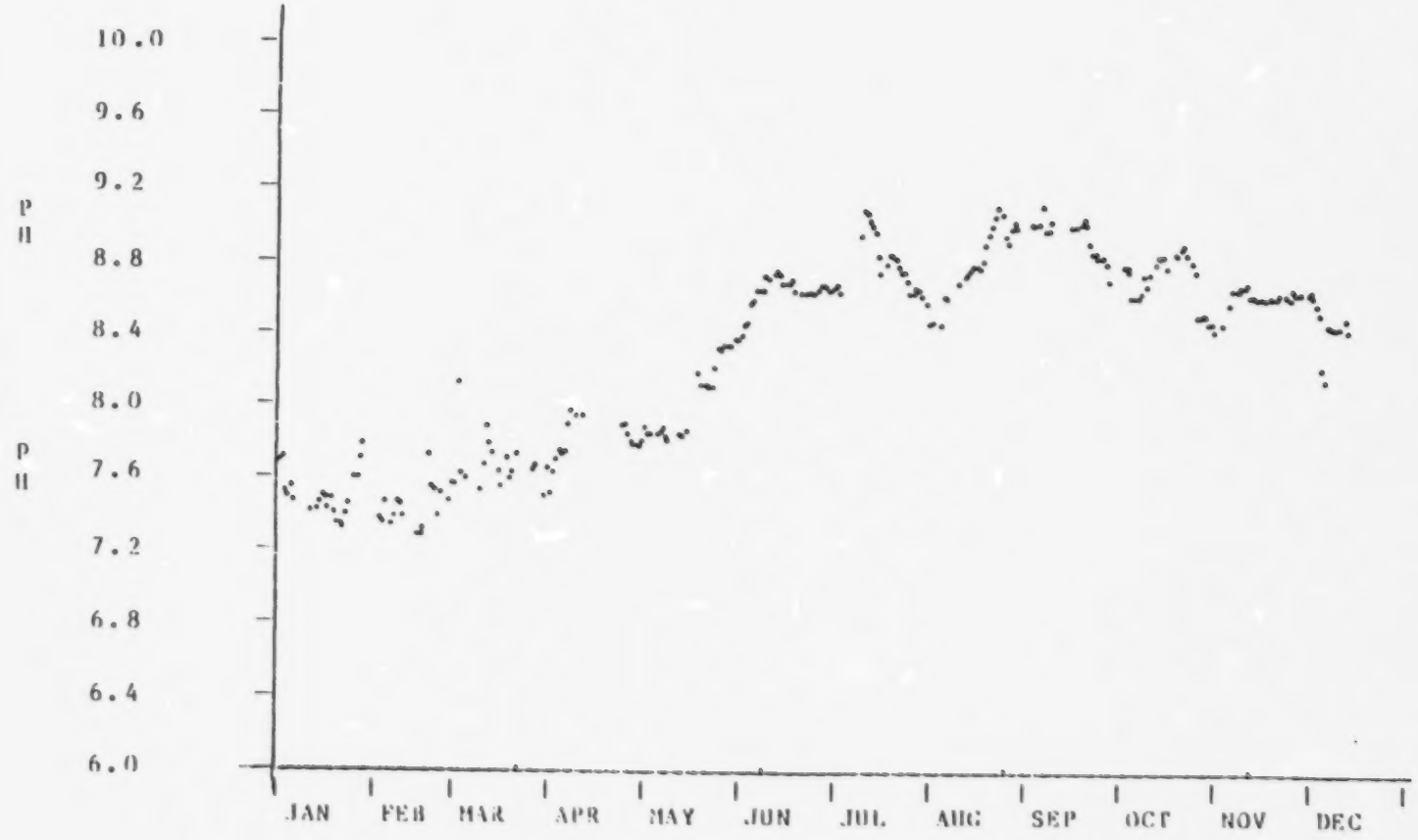

Figure 19. Mean Daily pH in the Souris River near Coulter during 1981.

Figure 20. Mean Daily pH in the Souris River near Coulter during 1982.

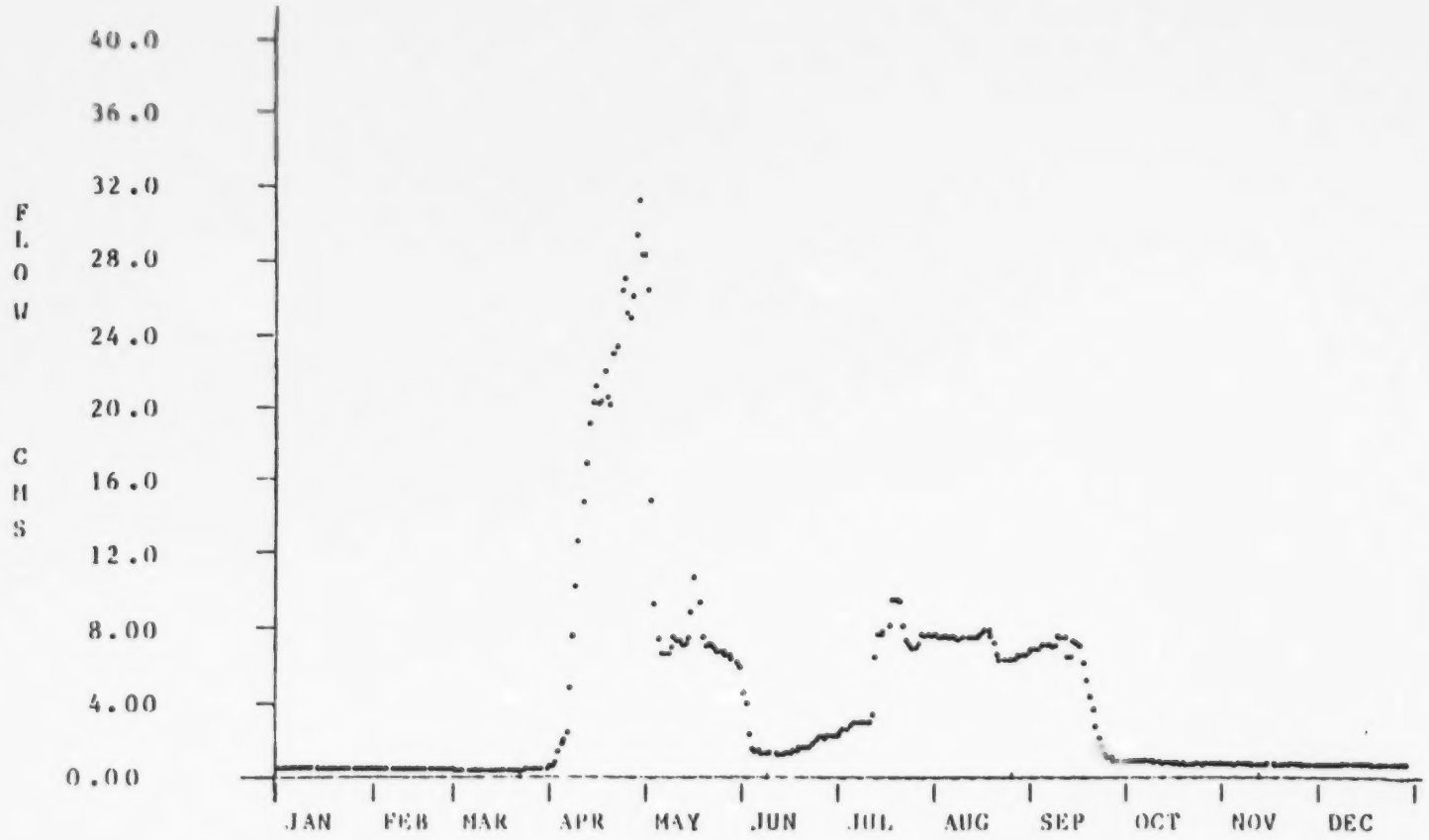

Figure 21. Mean Daily Flow in the Souris River near Coulter during 1978.

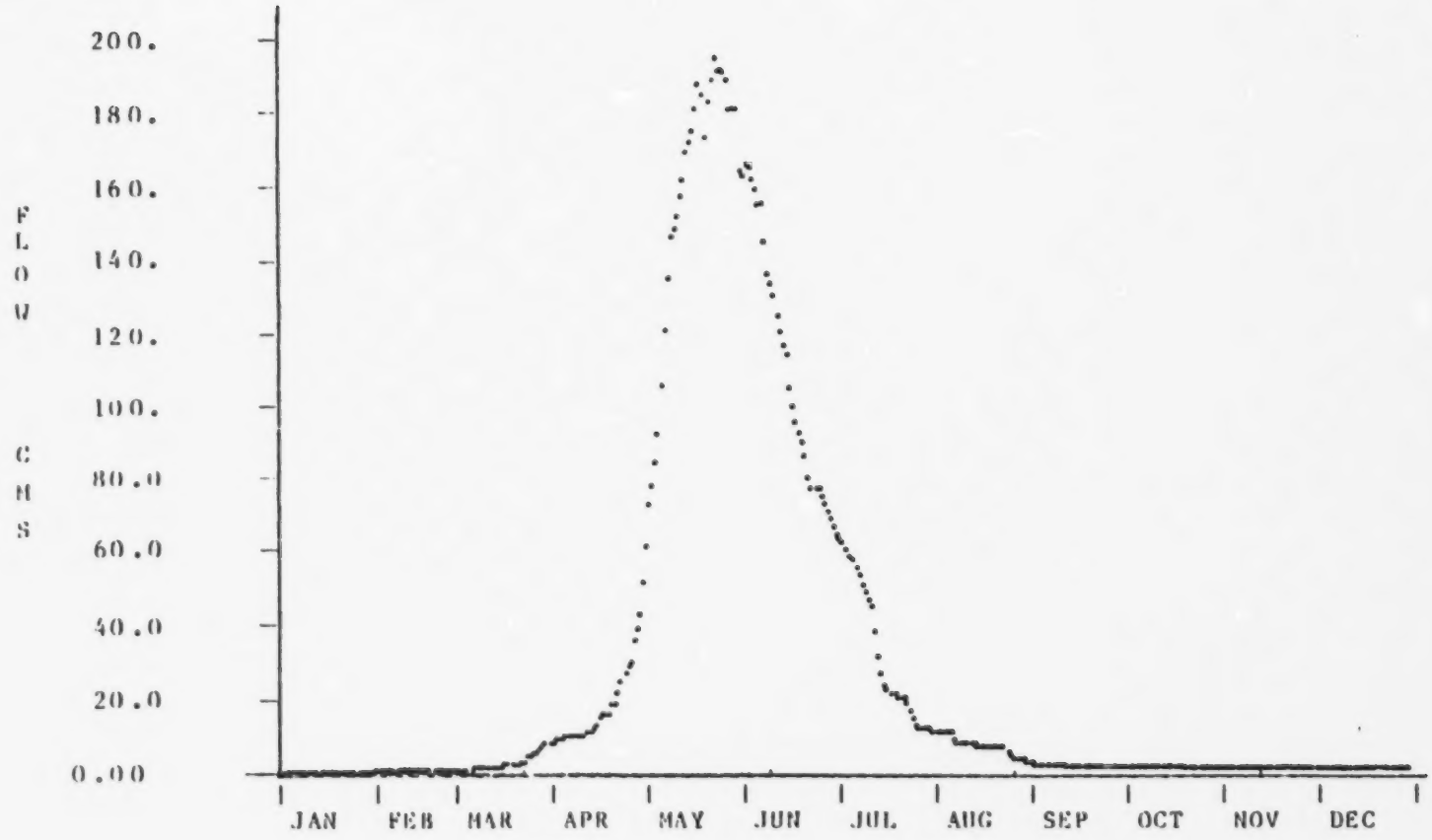

Figure 22. Mean Daily Flow in the Souris River near Coulter during 1979.

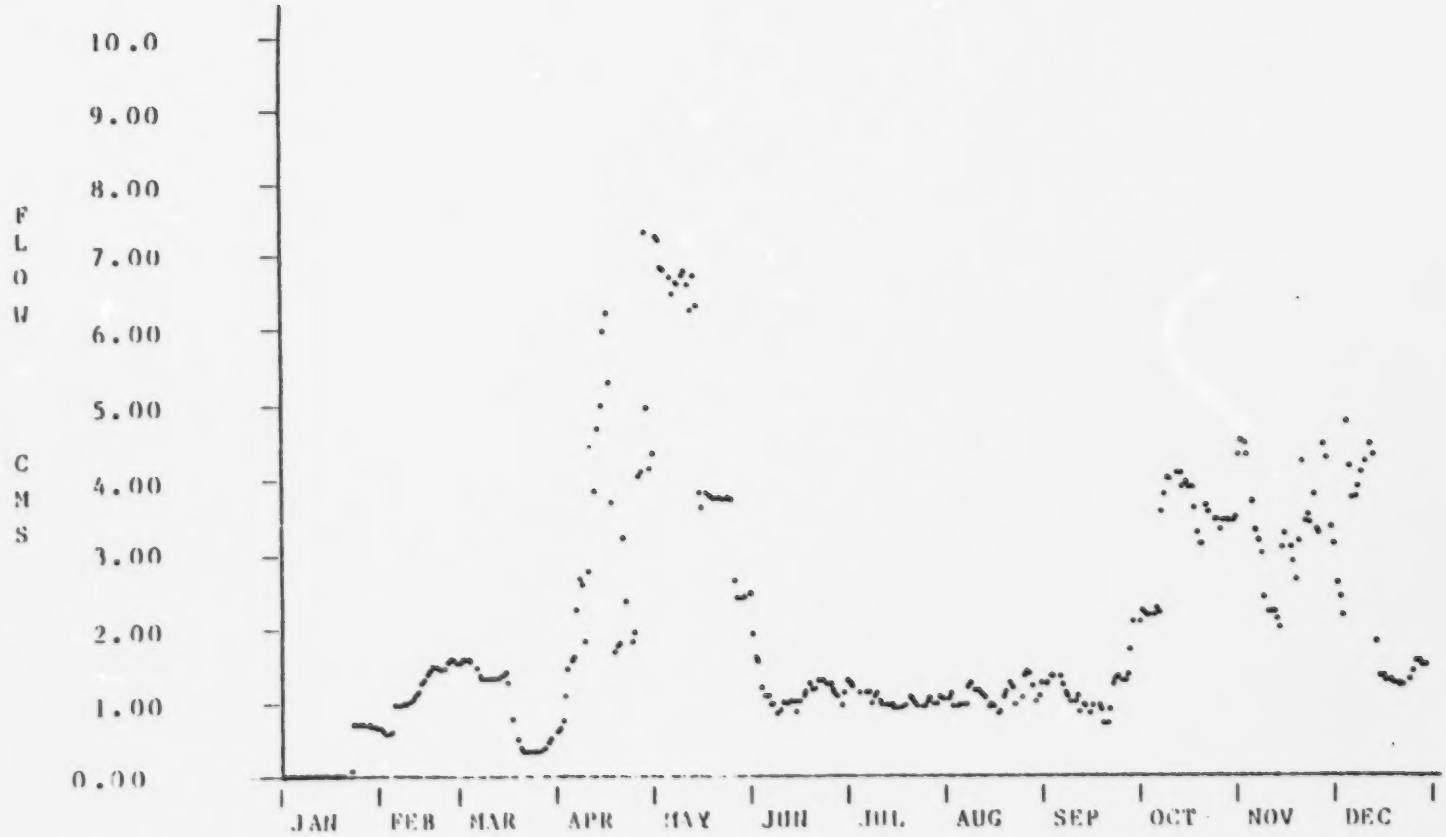

Figure 23. Mean Daily Flow in the Souris River near Coulter during 1980.

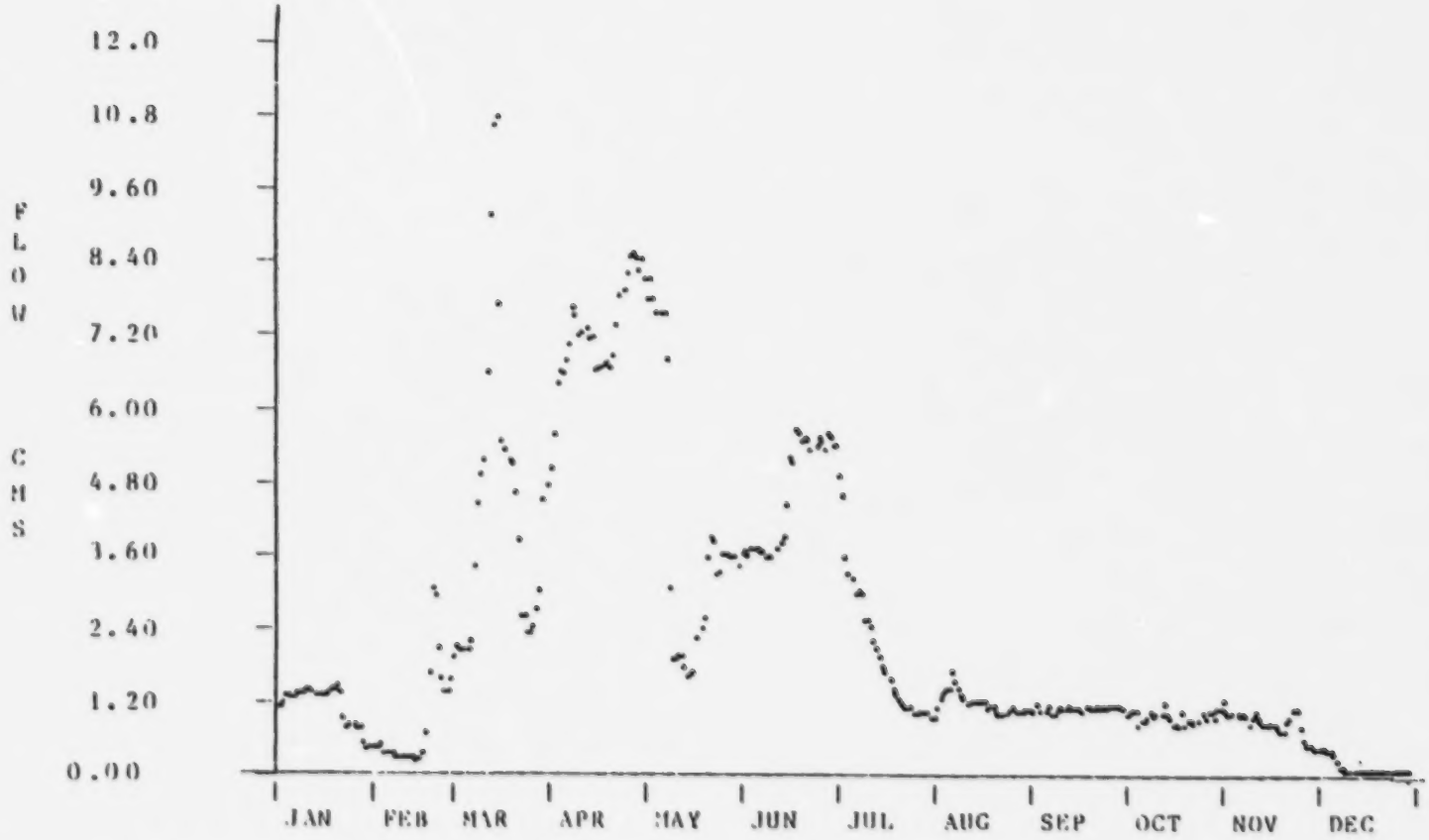

Figure 24. Mean Daily Flow in the Souris River near Coulter during 1981.

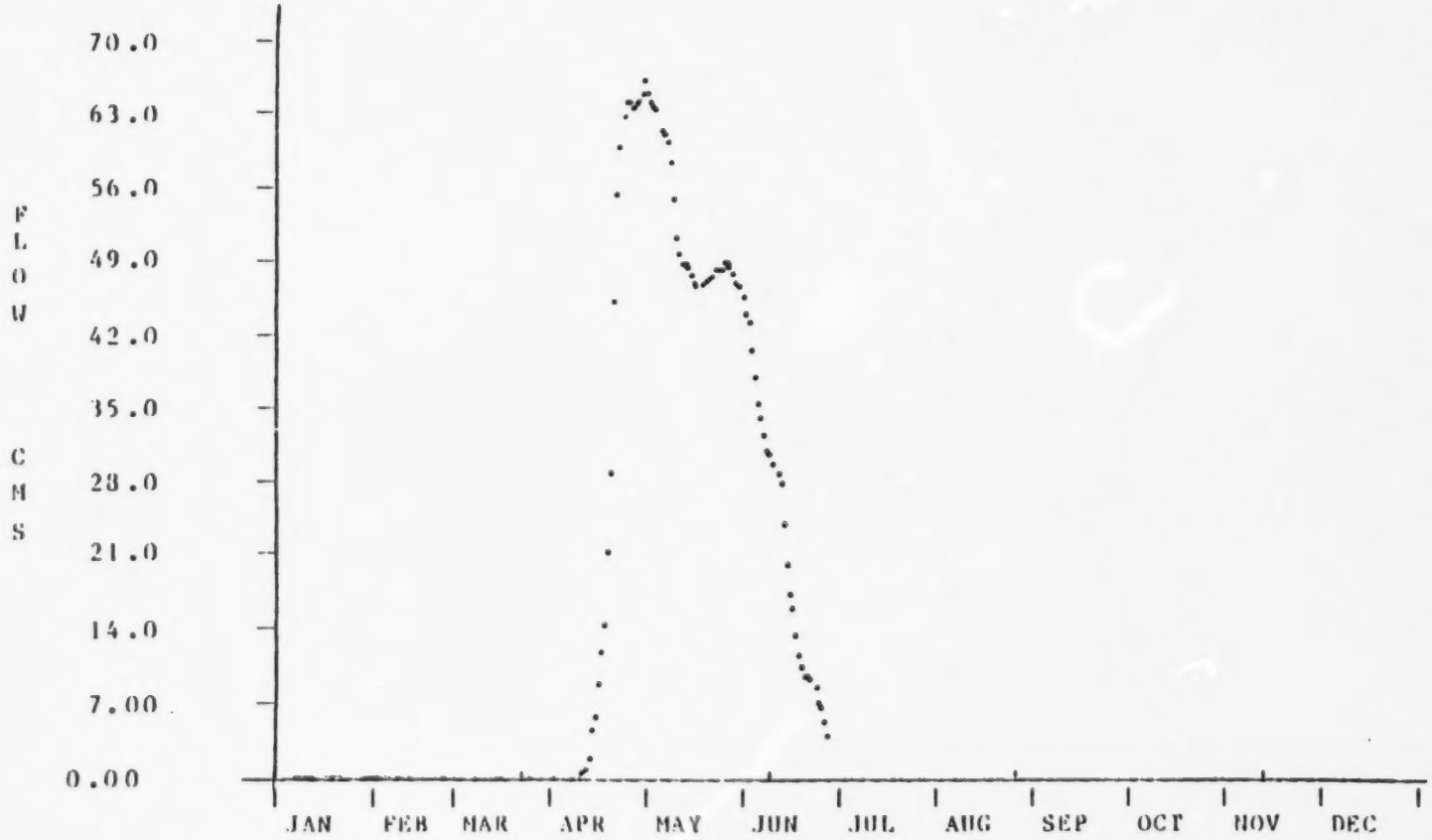

Figure 25. Mean Daily Flow in the Souris River near Coulter during 1982.

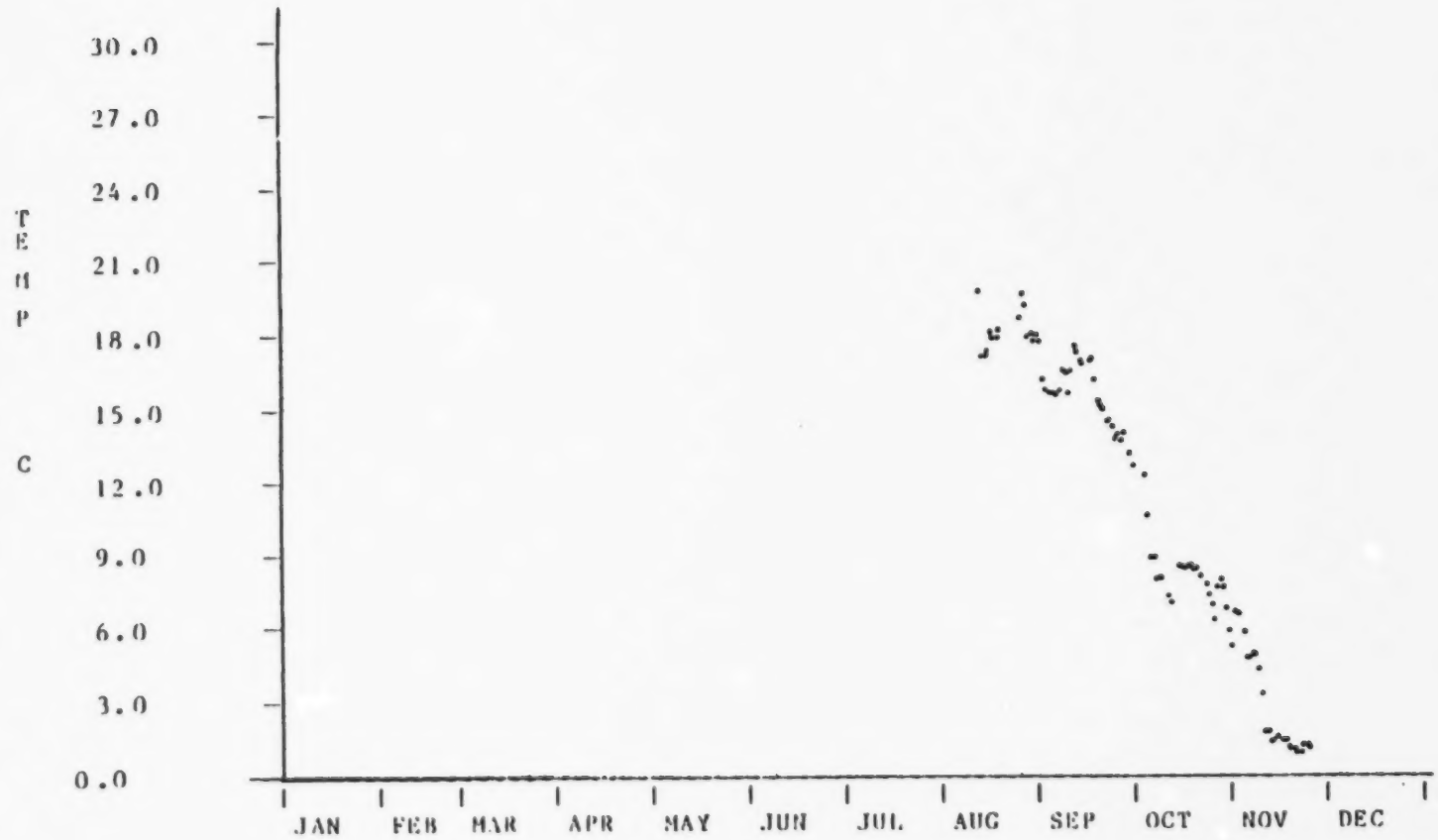

Figure 26. Mean Daily Temperature in the Souris River near Glen Ewen during 1977.

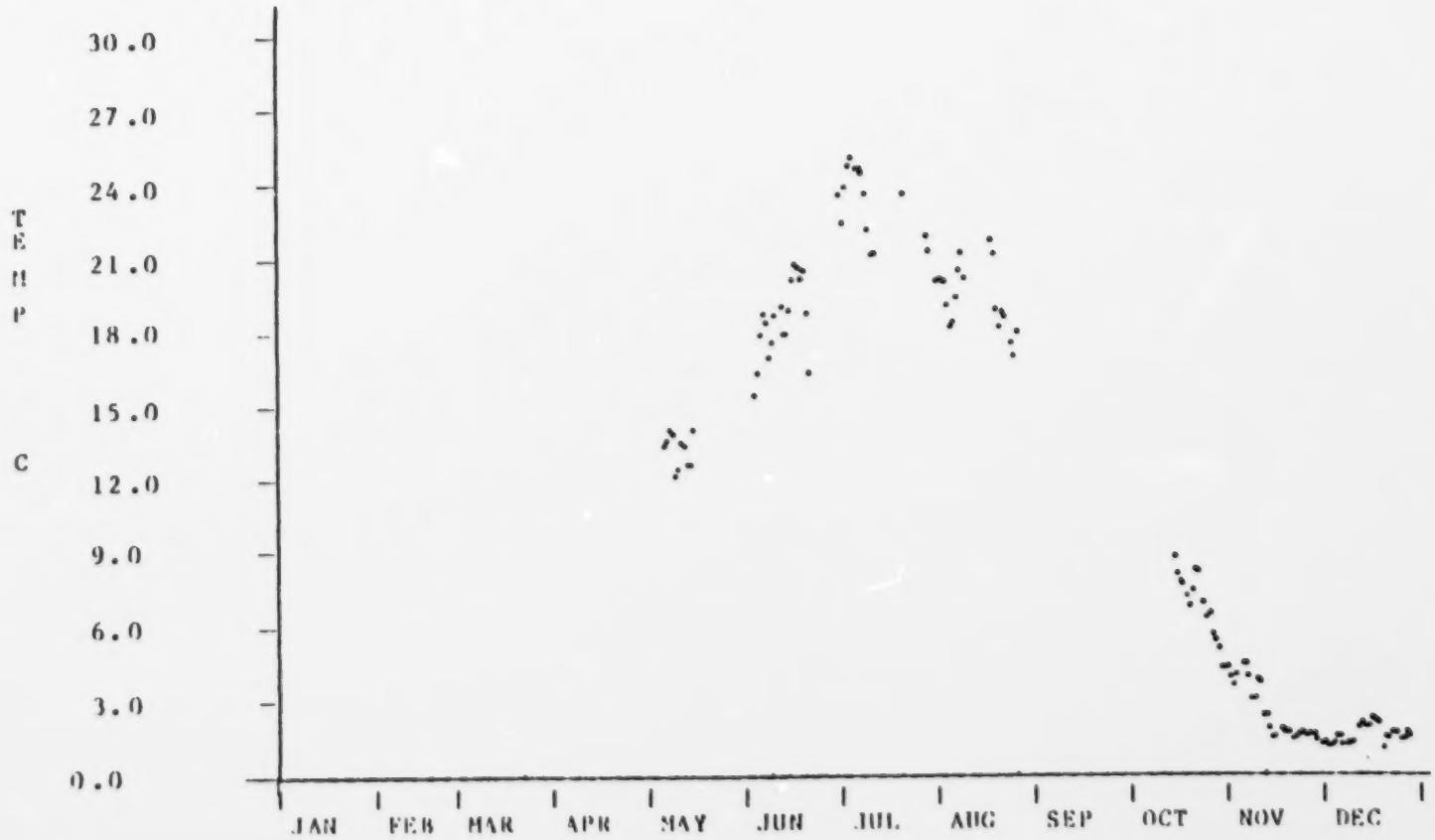

Figure 27. Mean Daily Temperature in the Souris River near Glen Ewen during 1978.

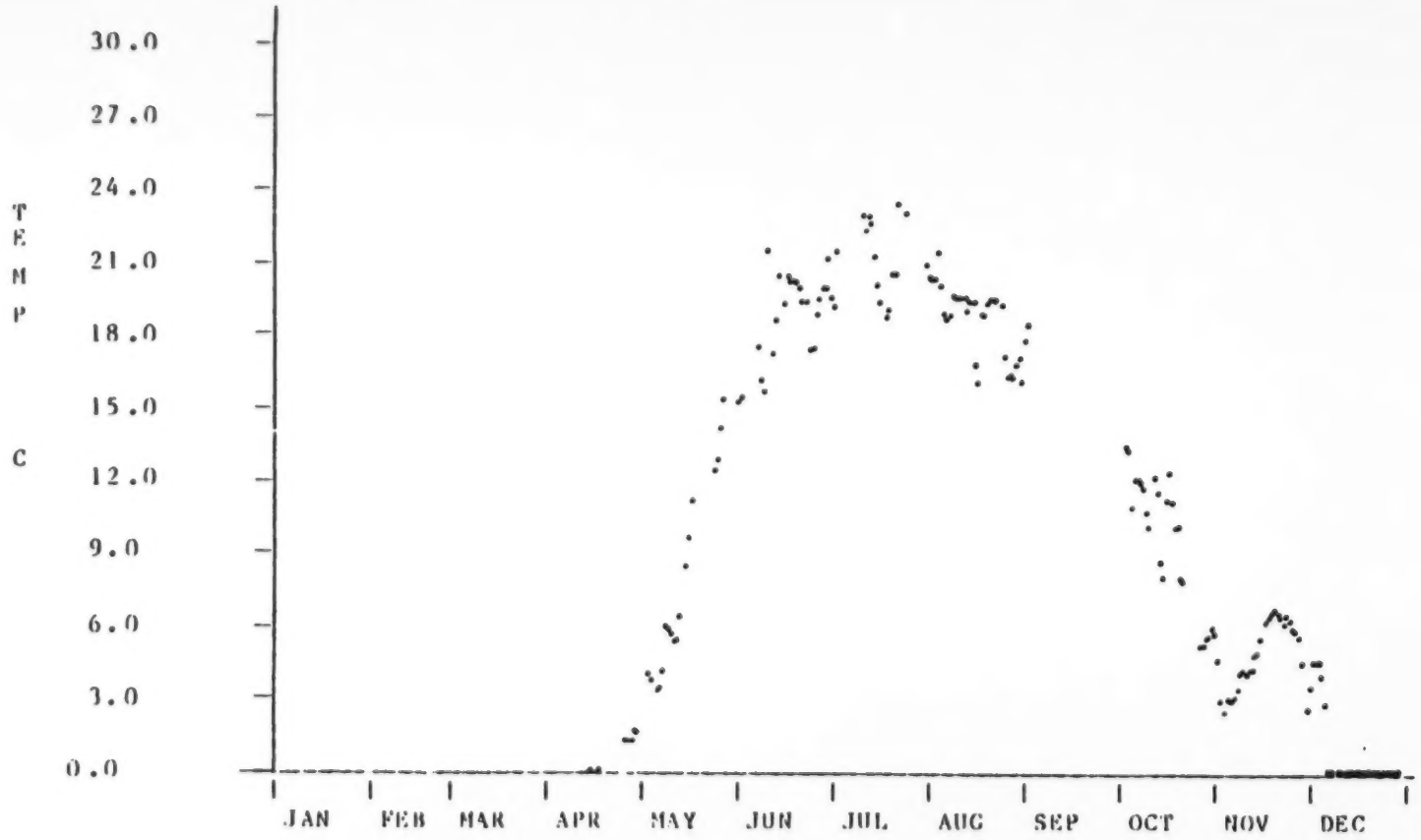

Figure 28. Mean Daily Temperature in the Souris River near Glen Ewen during 1979.

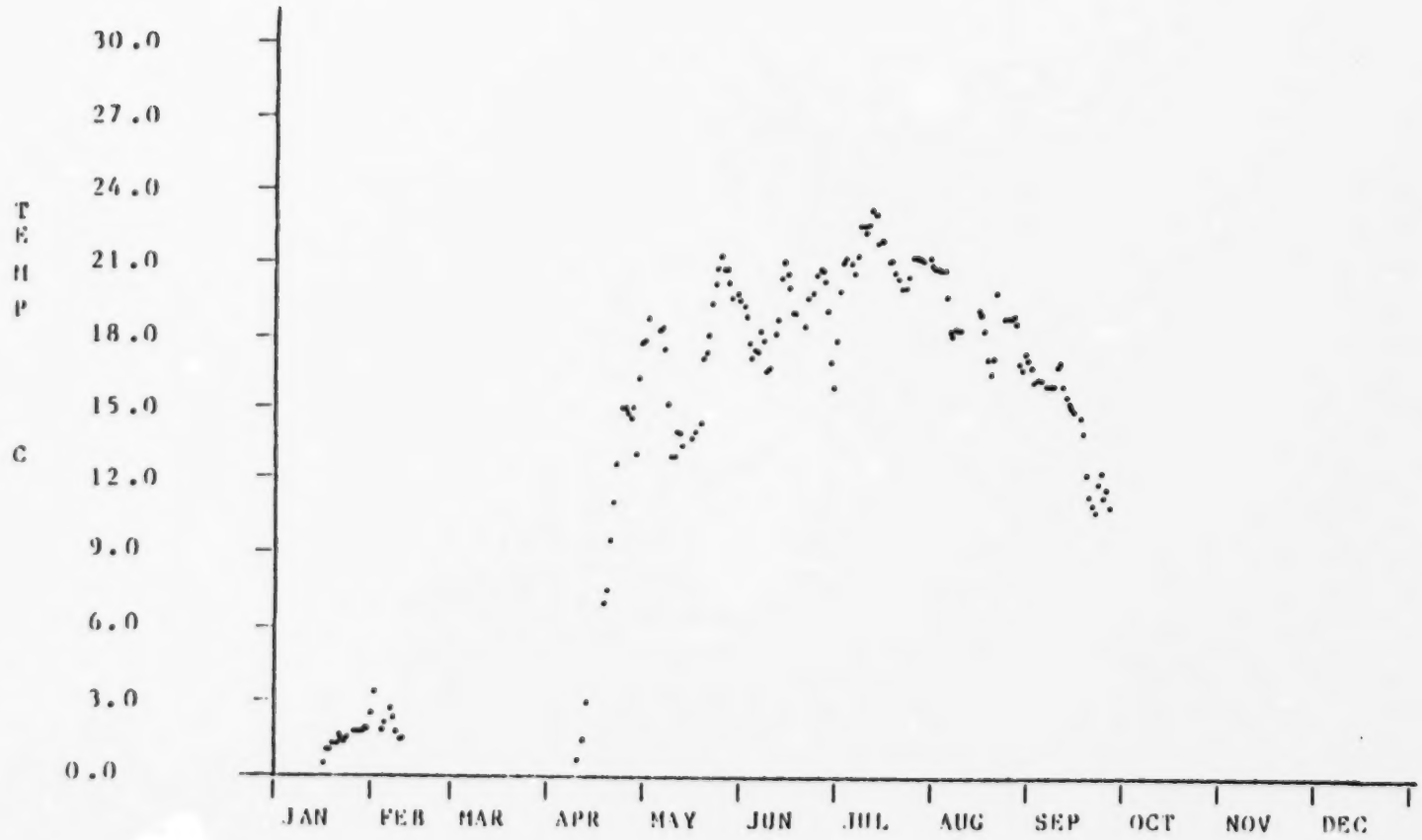

Figure 29. Mean Daily Temperature in the Souris River near Glen Ewen during 1980.

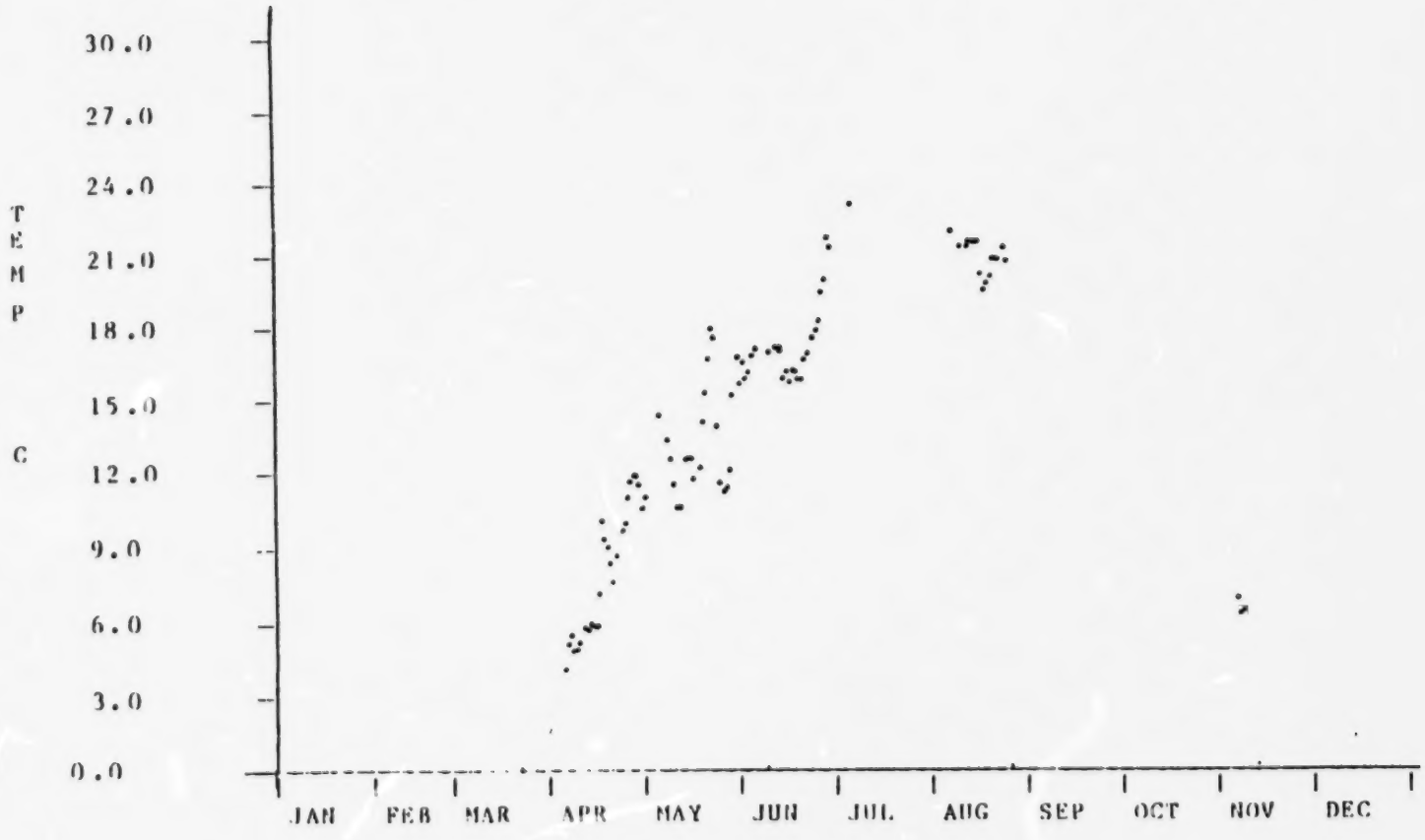

Figure 30. Mean Daily Temperature in the Souris River near Glen Ewen during 1981.

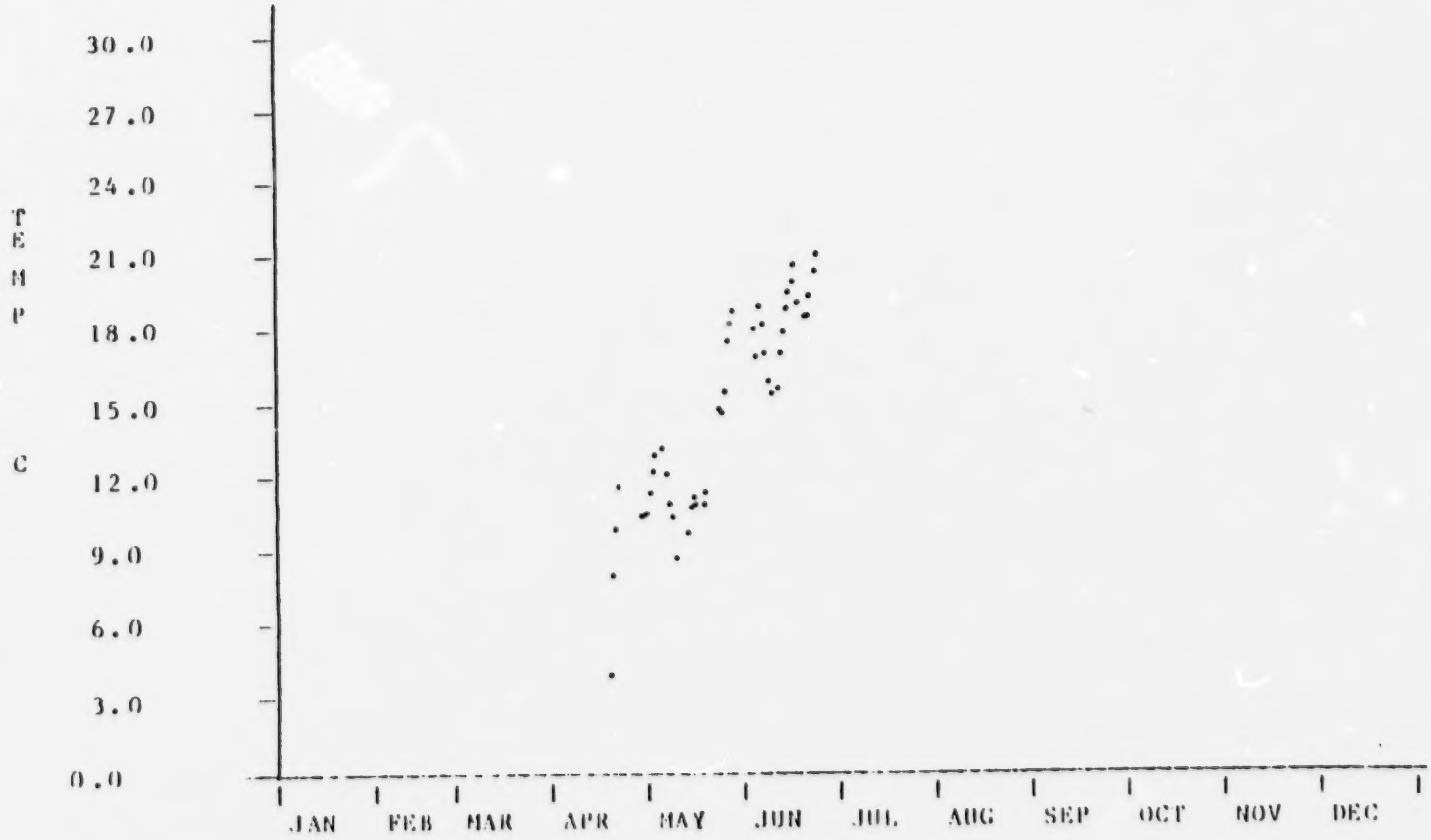

Figure 31. Mean Daily Temperature in the Souris River near Glen Ewen during 1982.

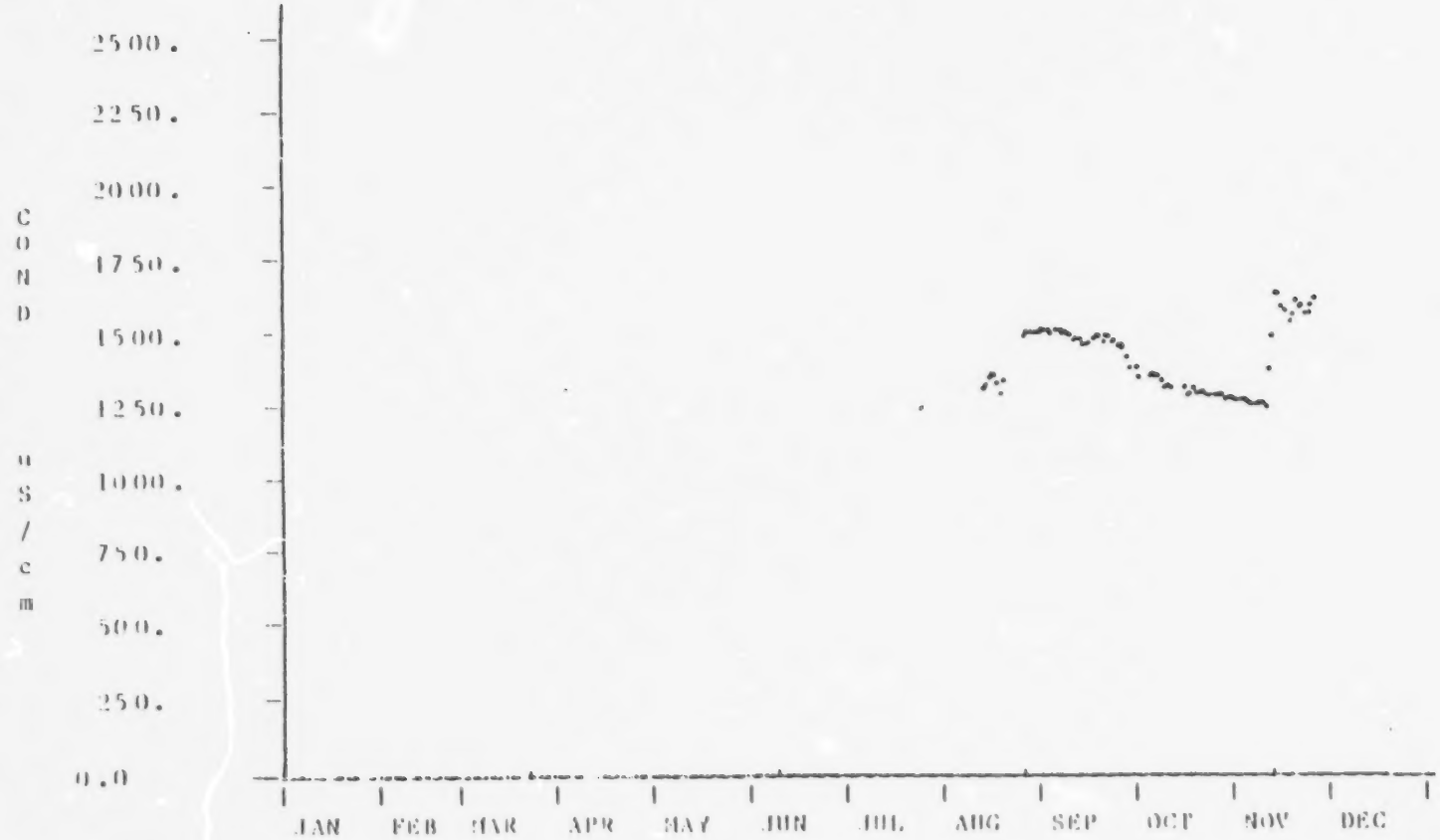

Figure 32. Mean Daily Conductivity in the Souris River near Glen Ewen during 1977.

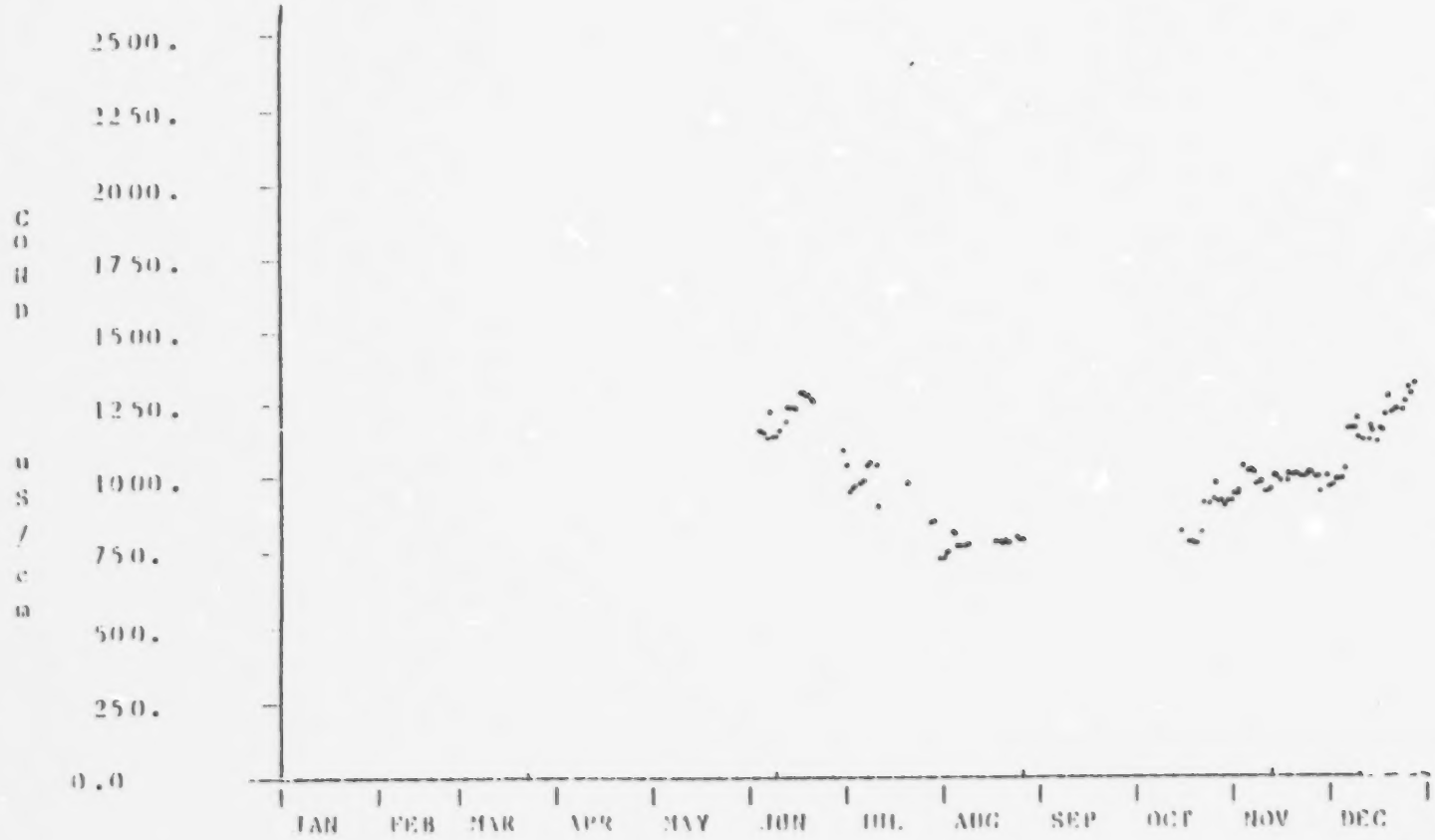

Figure 33. Mean Daily Conductivity in the Souris River near Glen Ewen during 1973.

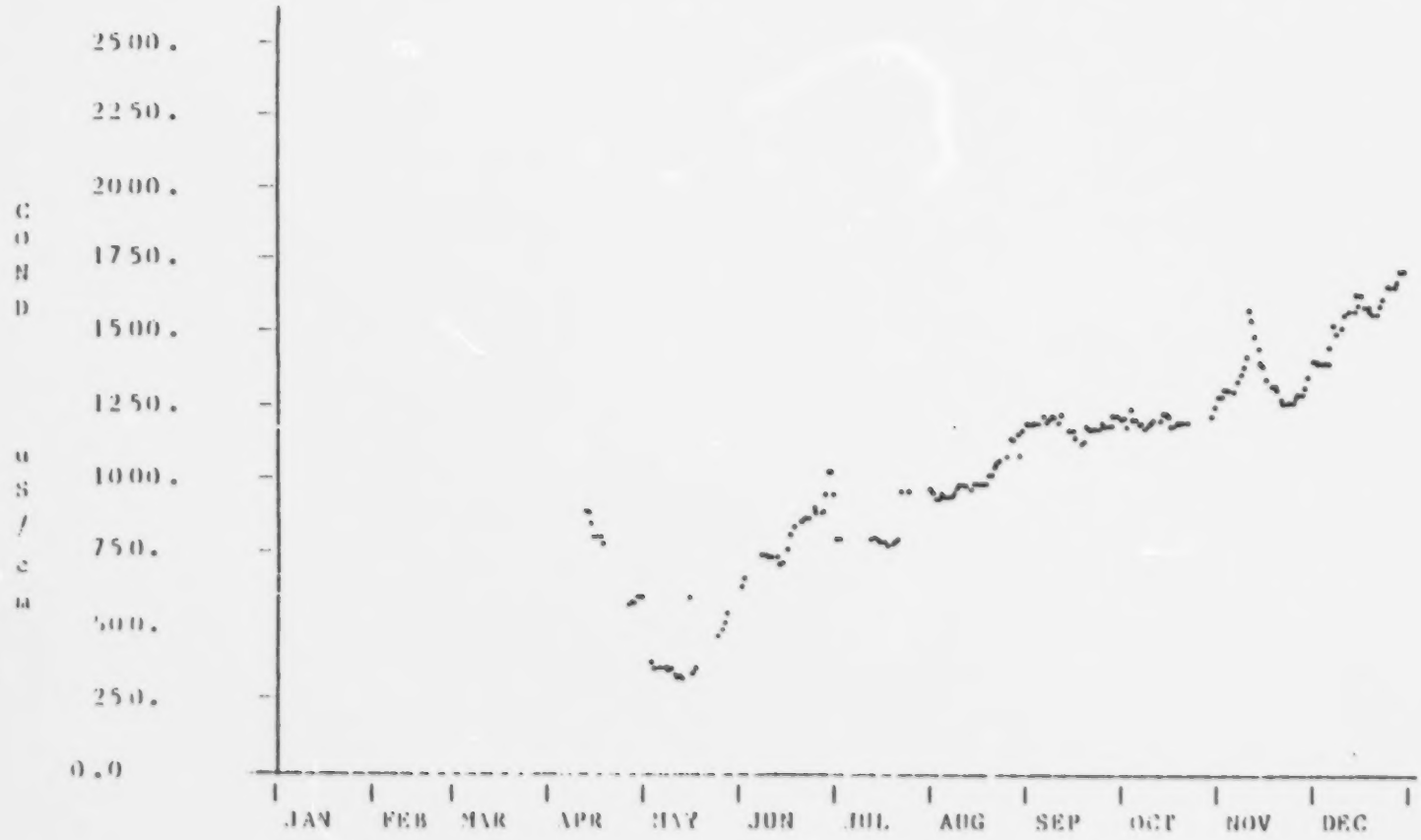

Figure 34. Mean Daily Conductivity in the Souris River near Glen Ewen during 1979.

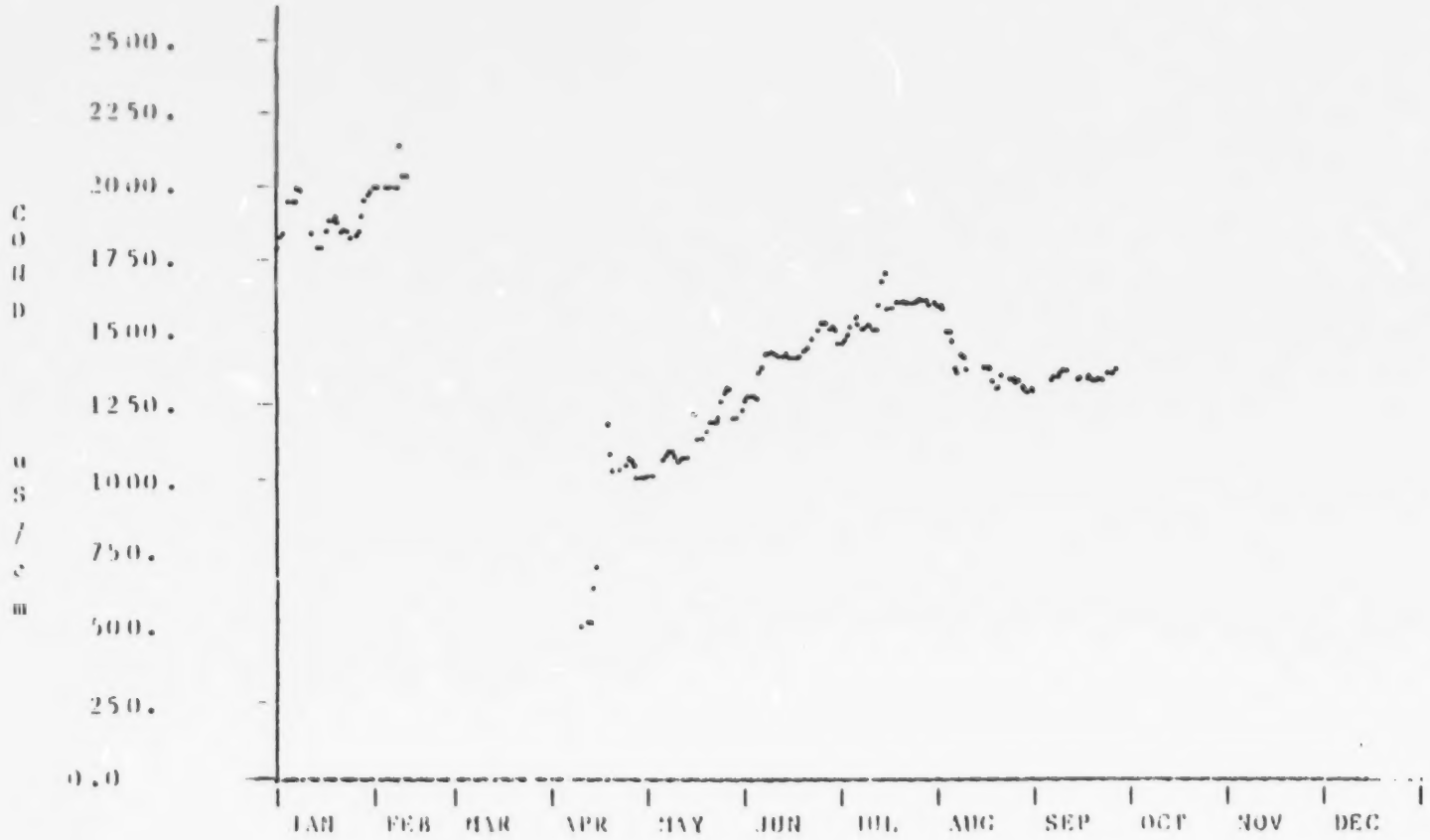

Figure 35. Mean Daily Conductivity in the Souris River near Glen Ewen during 1980.

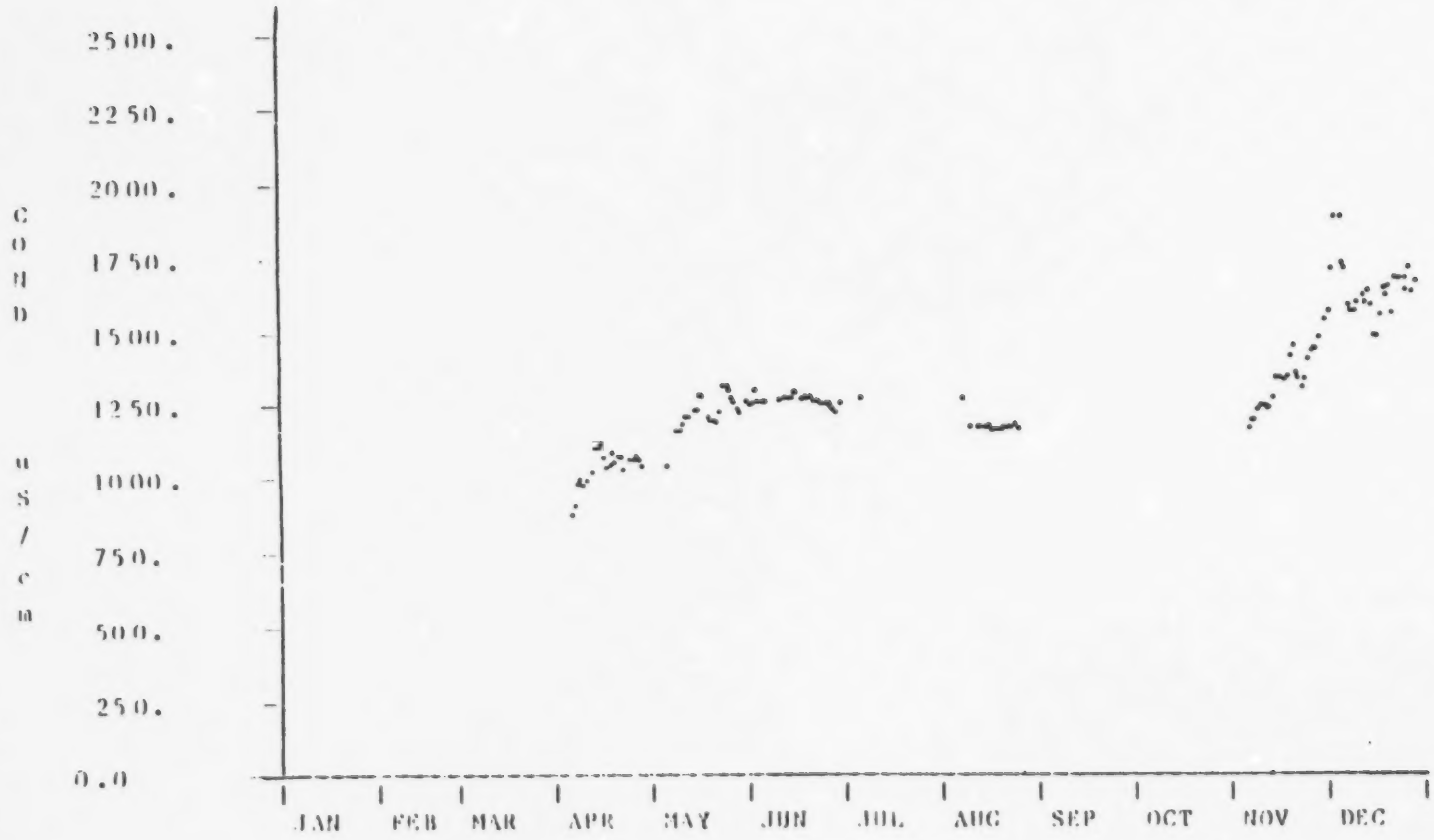

Figure 36. Mean Daily Conductivity in the Souris River near Glen Ewen during 1981.

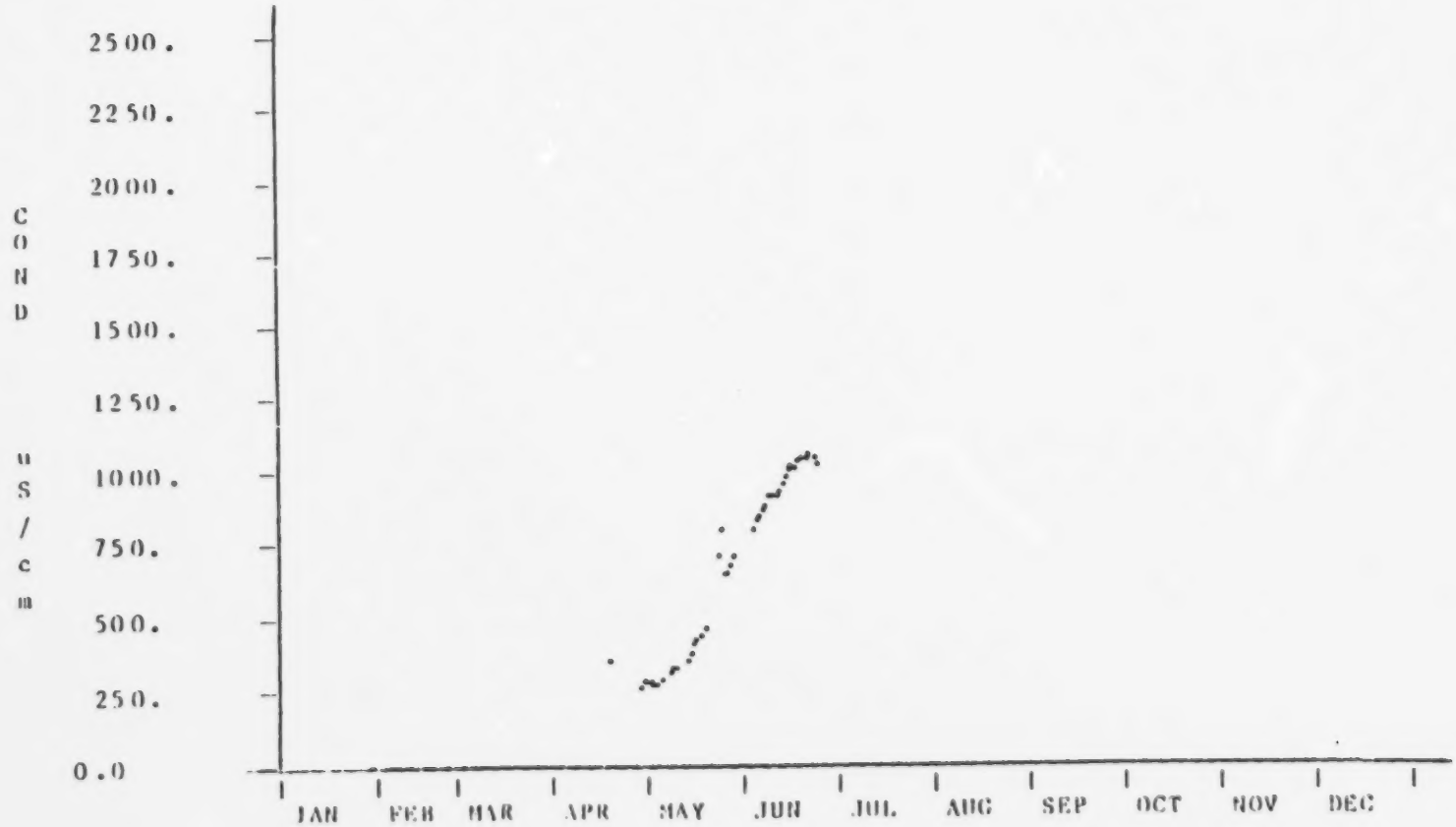

Figure 37. Mean Daily Conductivity in the Souris River near Glen Ewen during 1982.

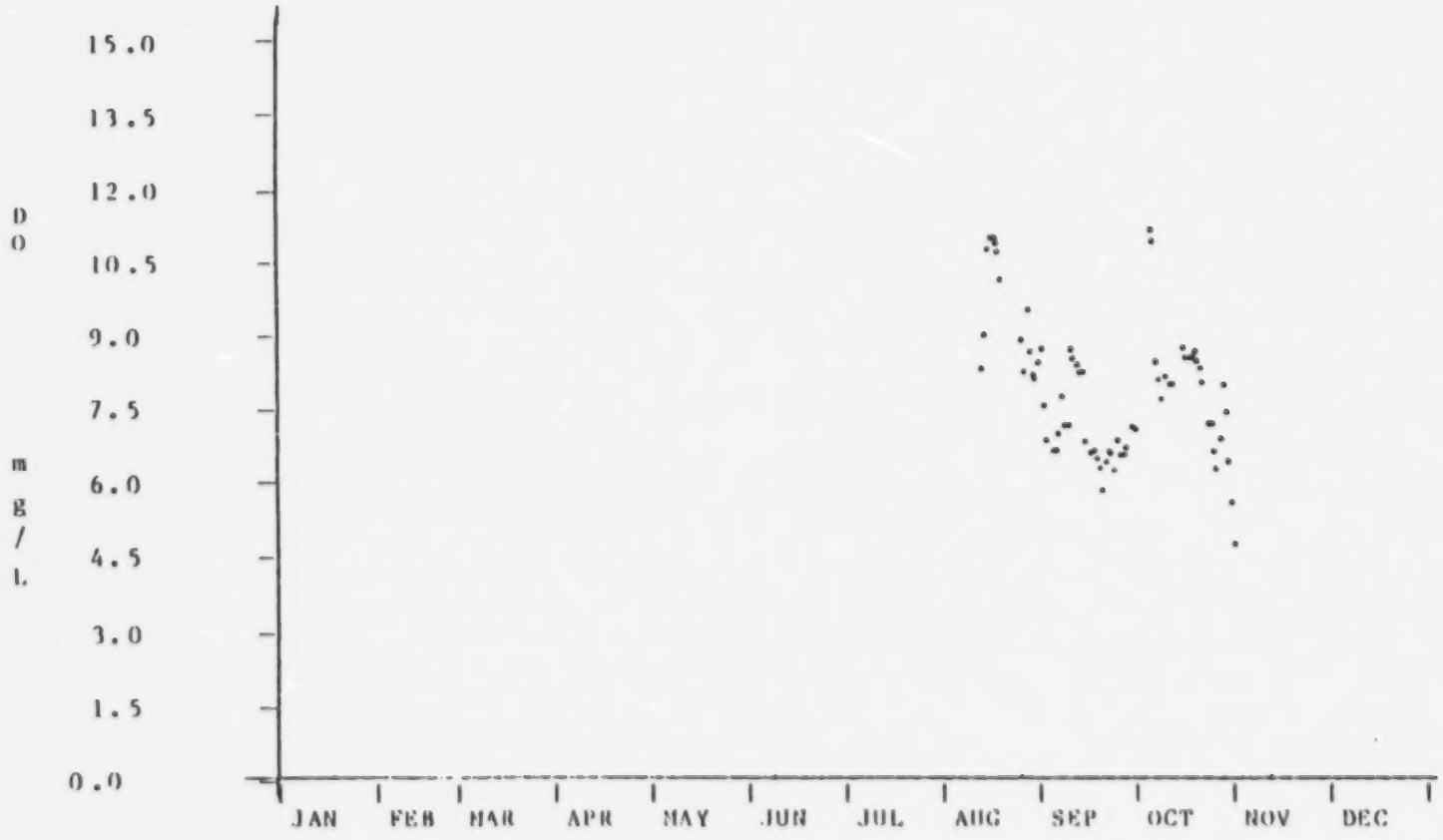

Figure 38. Mean Daily Dissolved Oxygen in the Souris River near Glen Ewen during 1977.

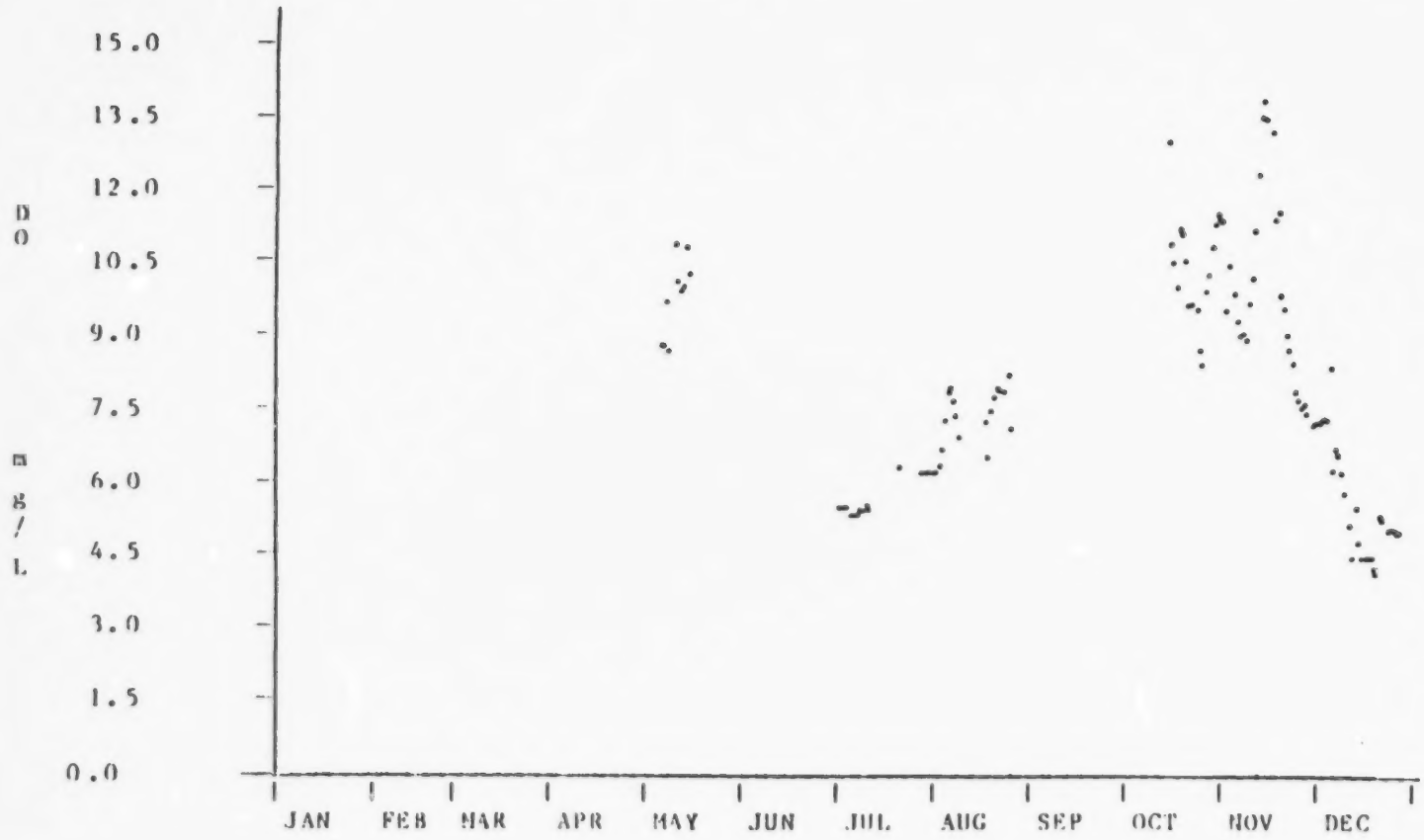

Figure 39. Mean Daily Dissolved Oxygen in the Souris River near Glen Ewen during 1978.

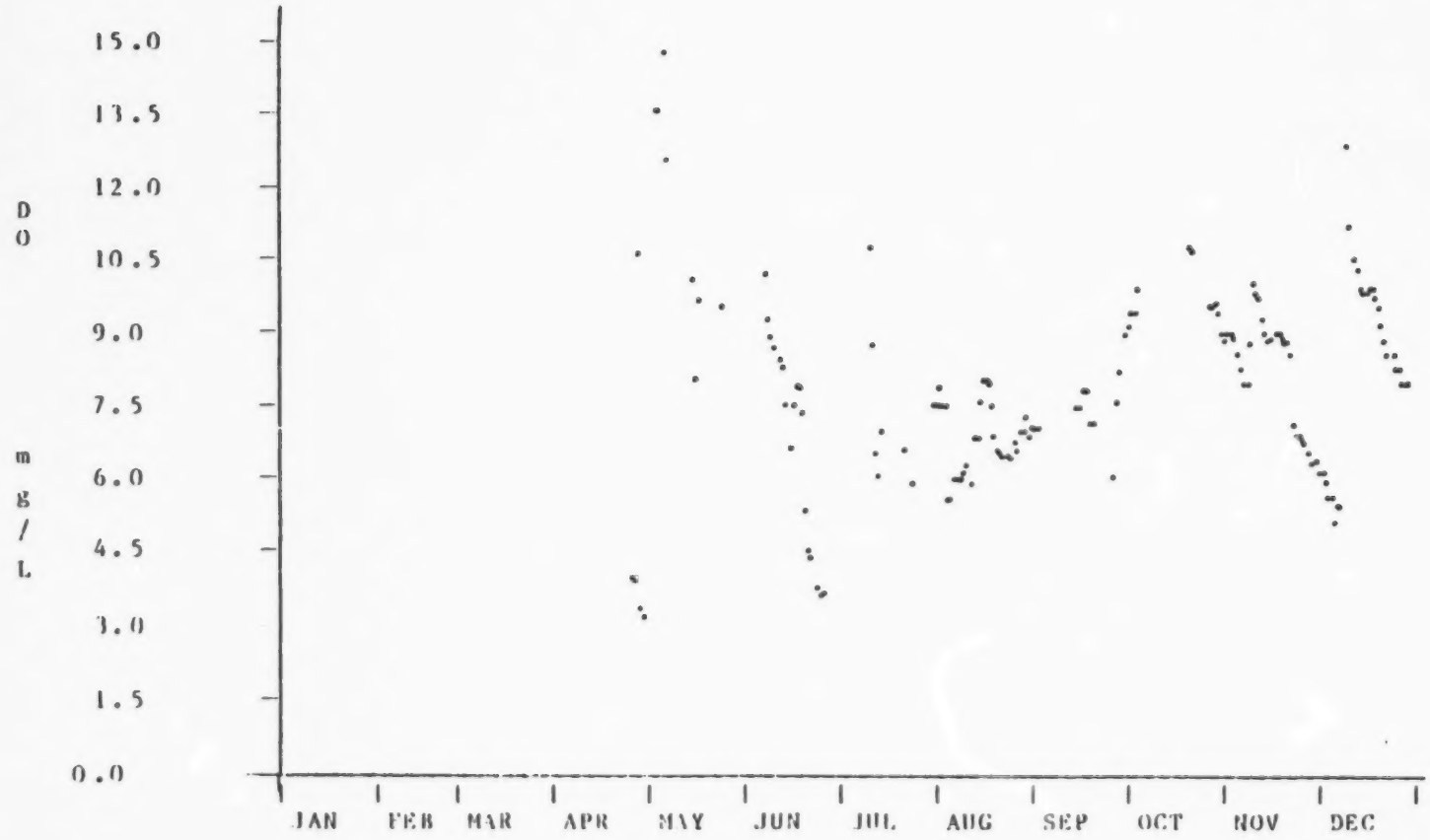

Figure 40. Mean Daily Dissolved Oxygen in the Souris River near Glen Ewen during 1979.

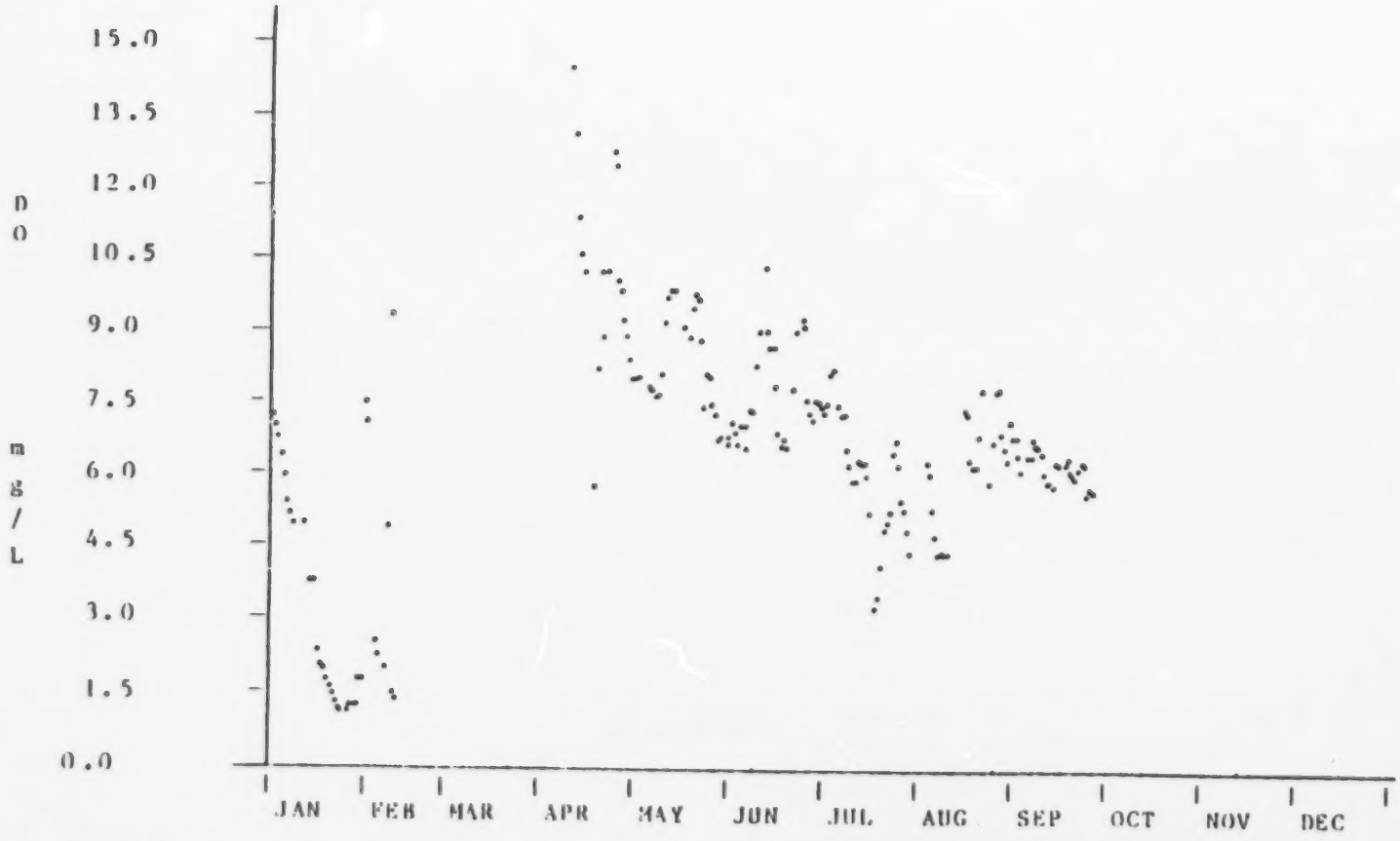

Figure 41. Mean Daily Dissolved Oxygen in the Souris River near Glen Ewen during 1980.

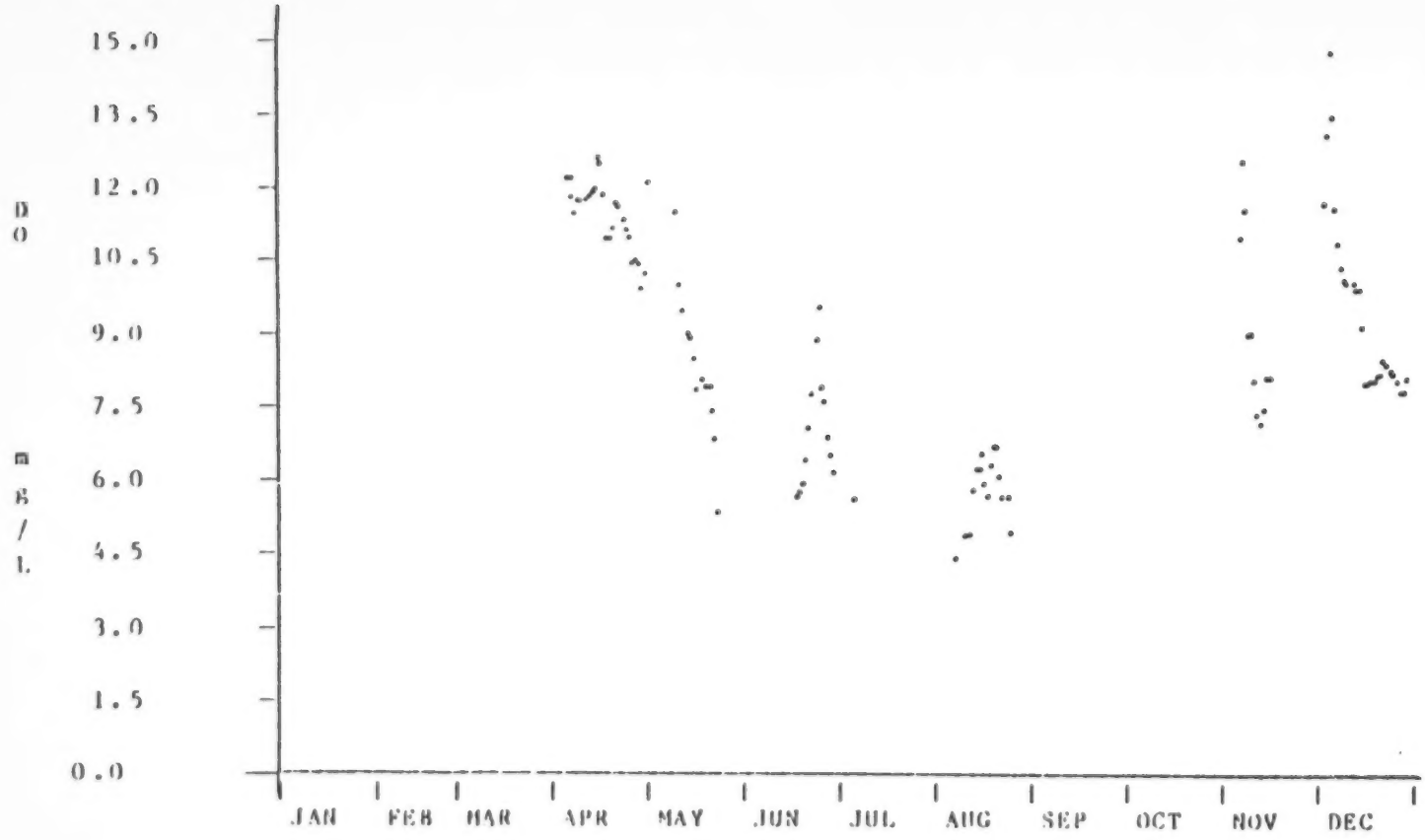

Figure 42. Mean Daily Dissolved Oxygen in the Souris River near Glen Ewen during 1981.

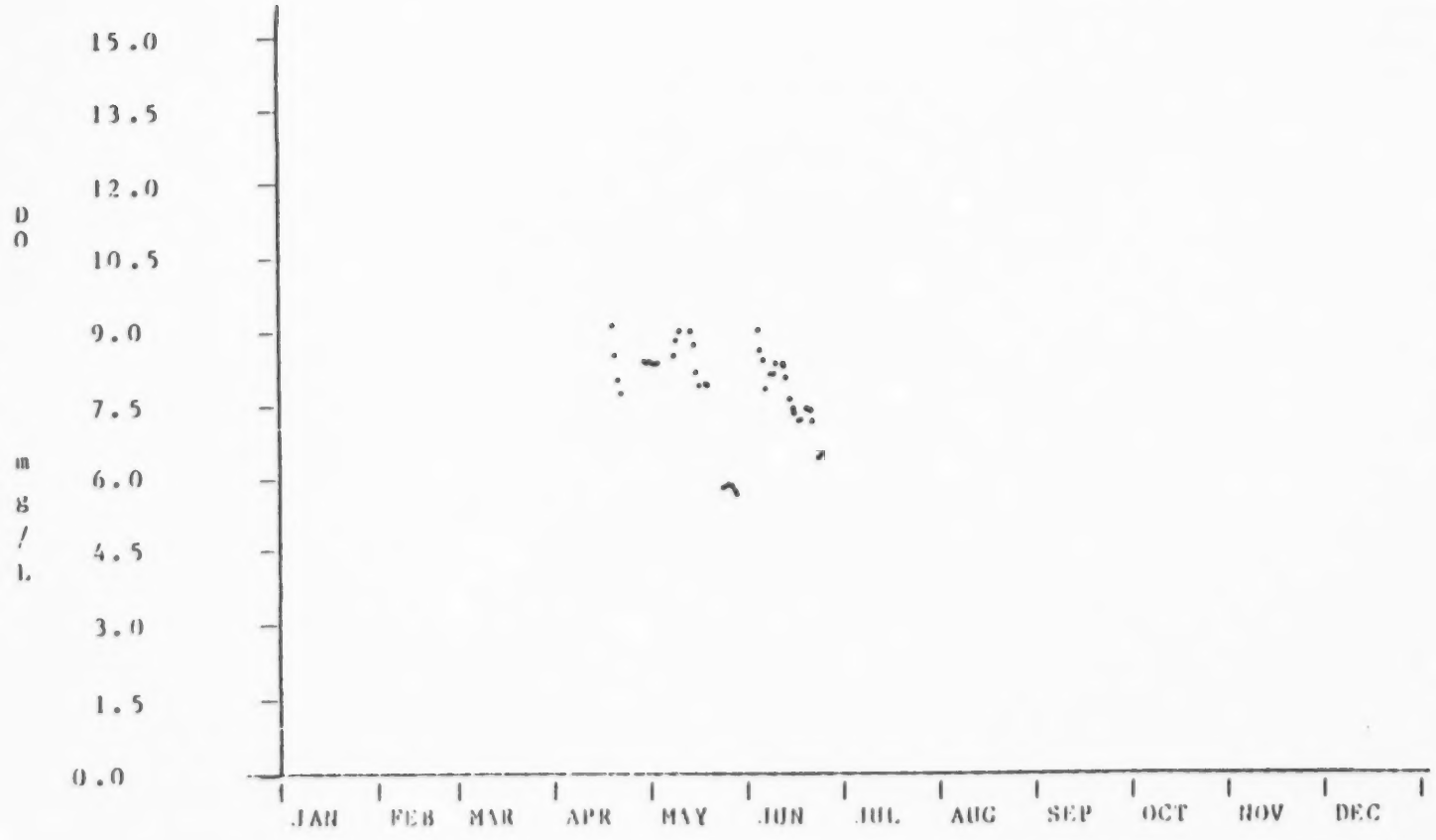

Figure 43. Mean Daily Dissolved Oxygen in the Souris River near Glen Ewen during 1982.

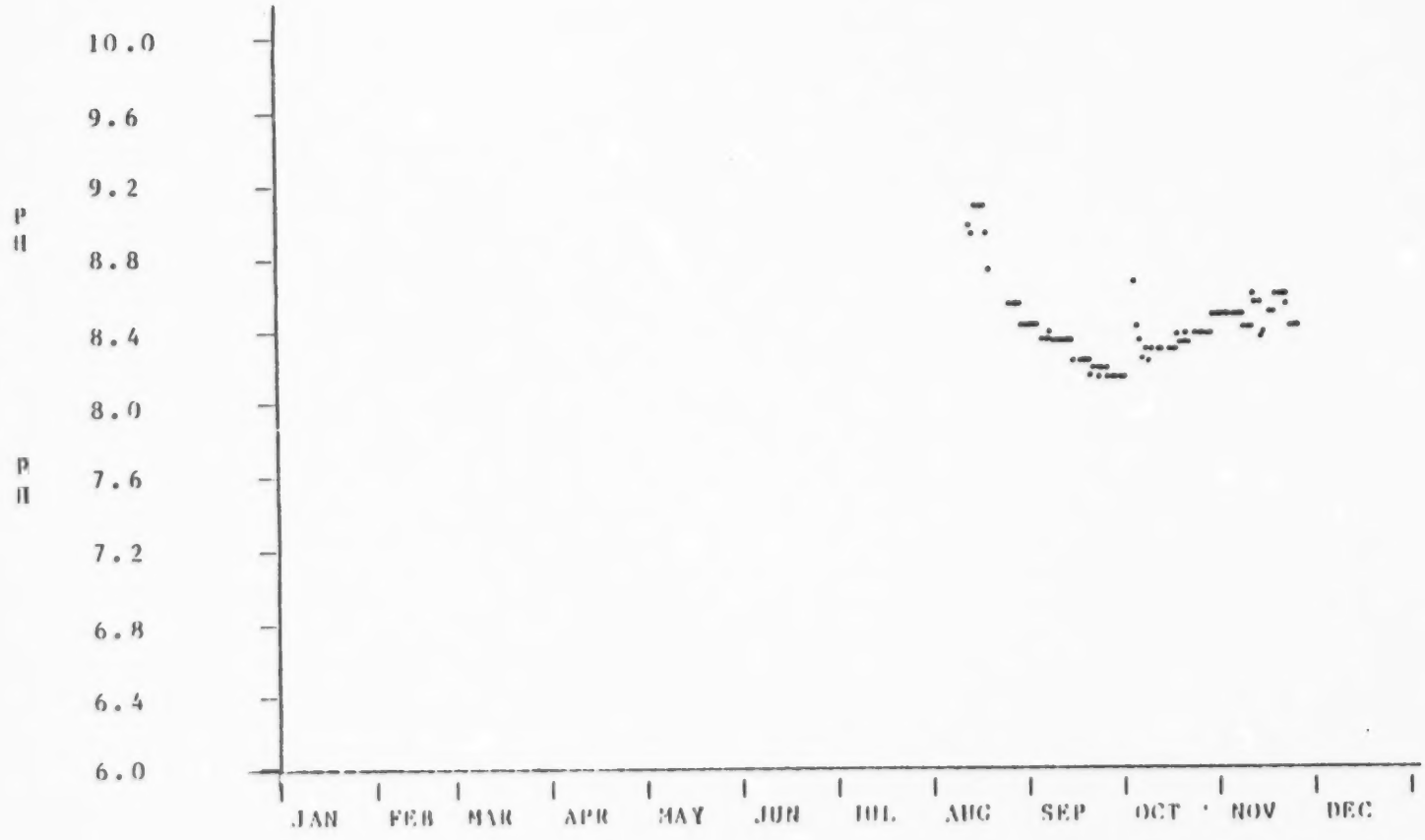

Figure 44. Mean Daily pH in the Souris River near Glen Ewen during 1977.

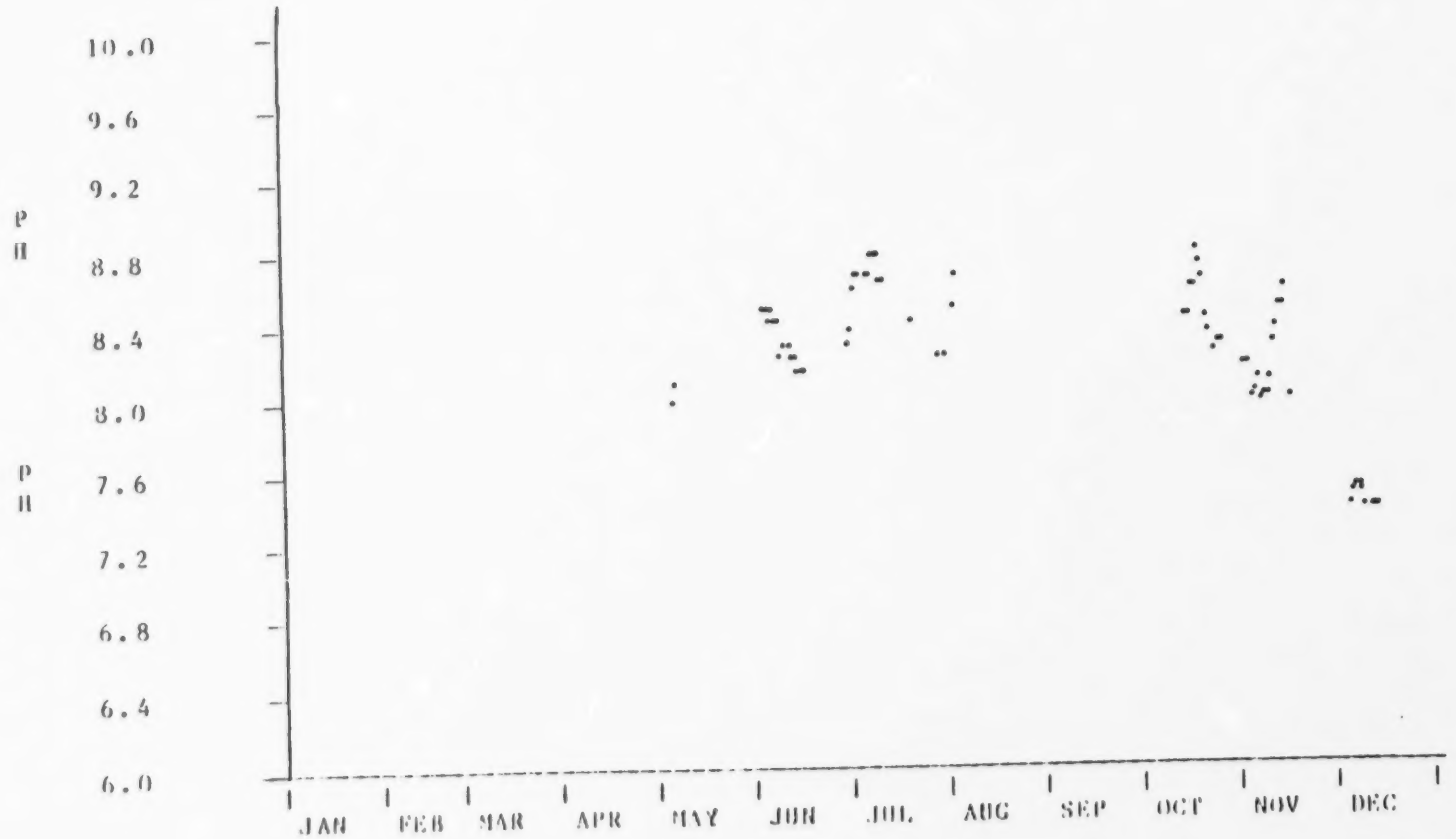

Figure 45. Mean Daily pH in the Souris River near Glen Ewen during 1978.

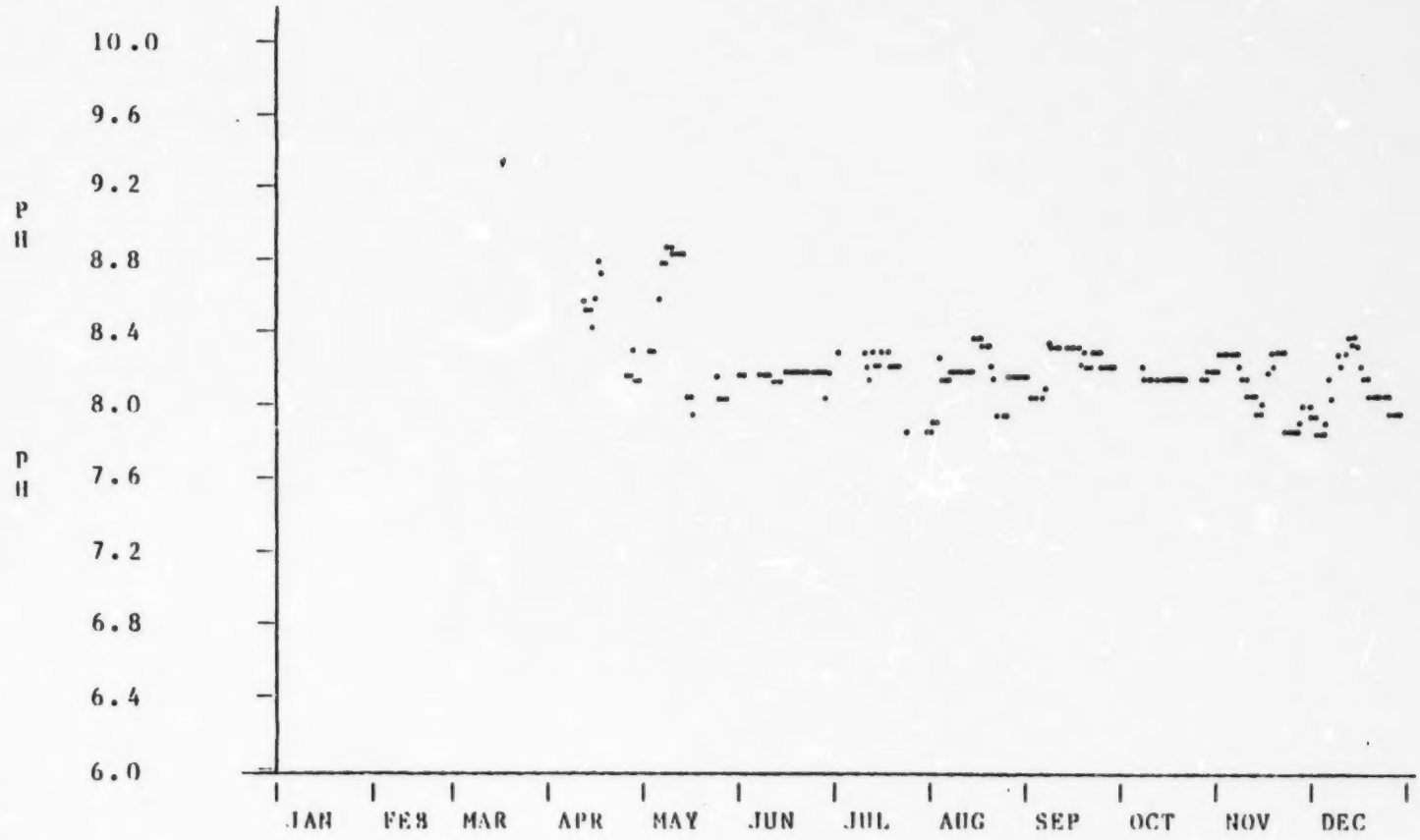

Figure 46. Mean Daily pH in the Souris River near Glen Ewen during 1979.

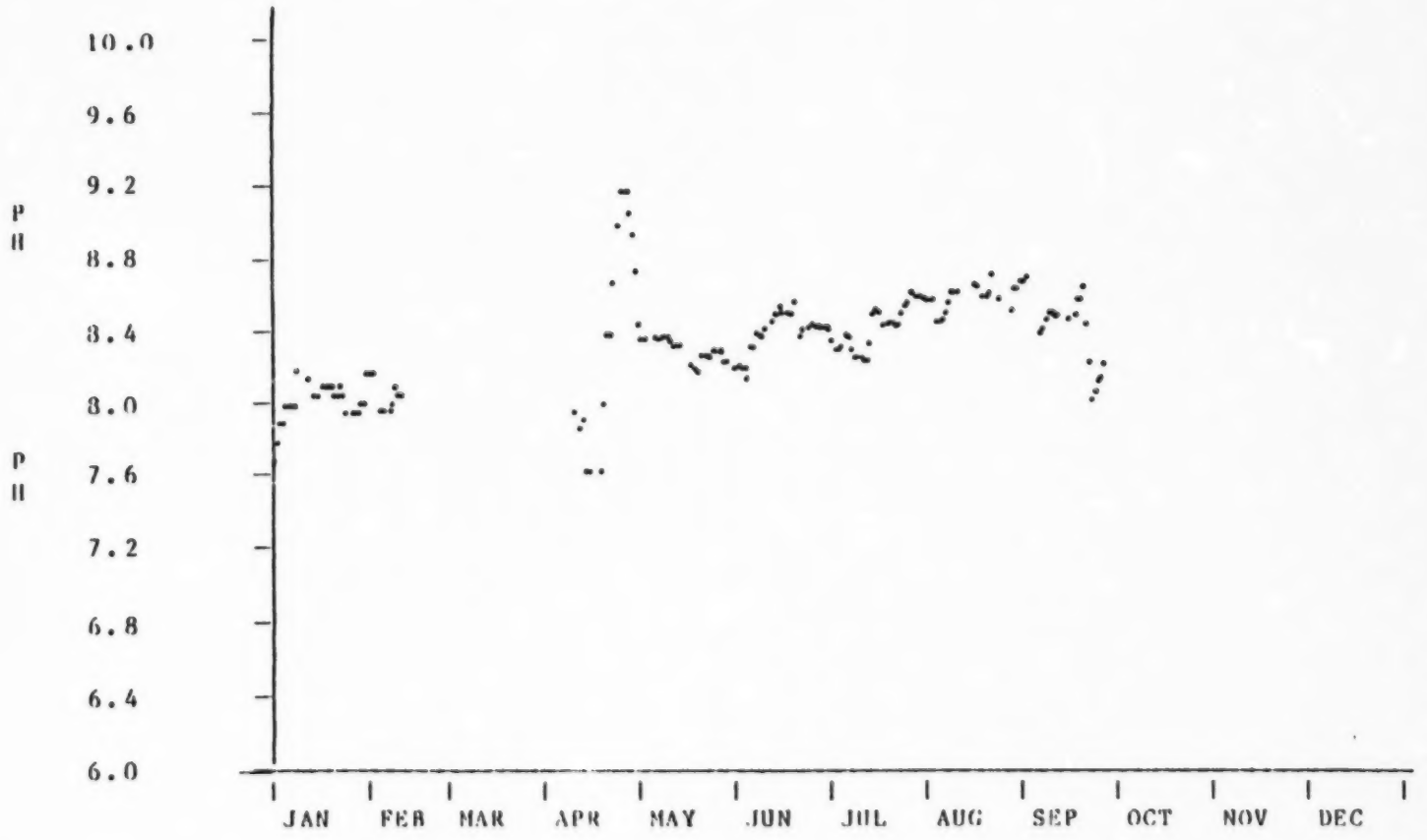

Figure 47. Mean Daily pH in the Souris River near Glen Ewen during 1980.

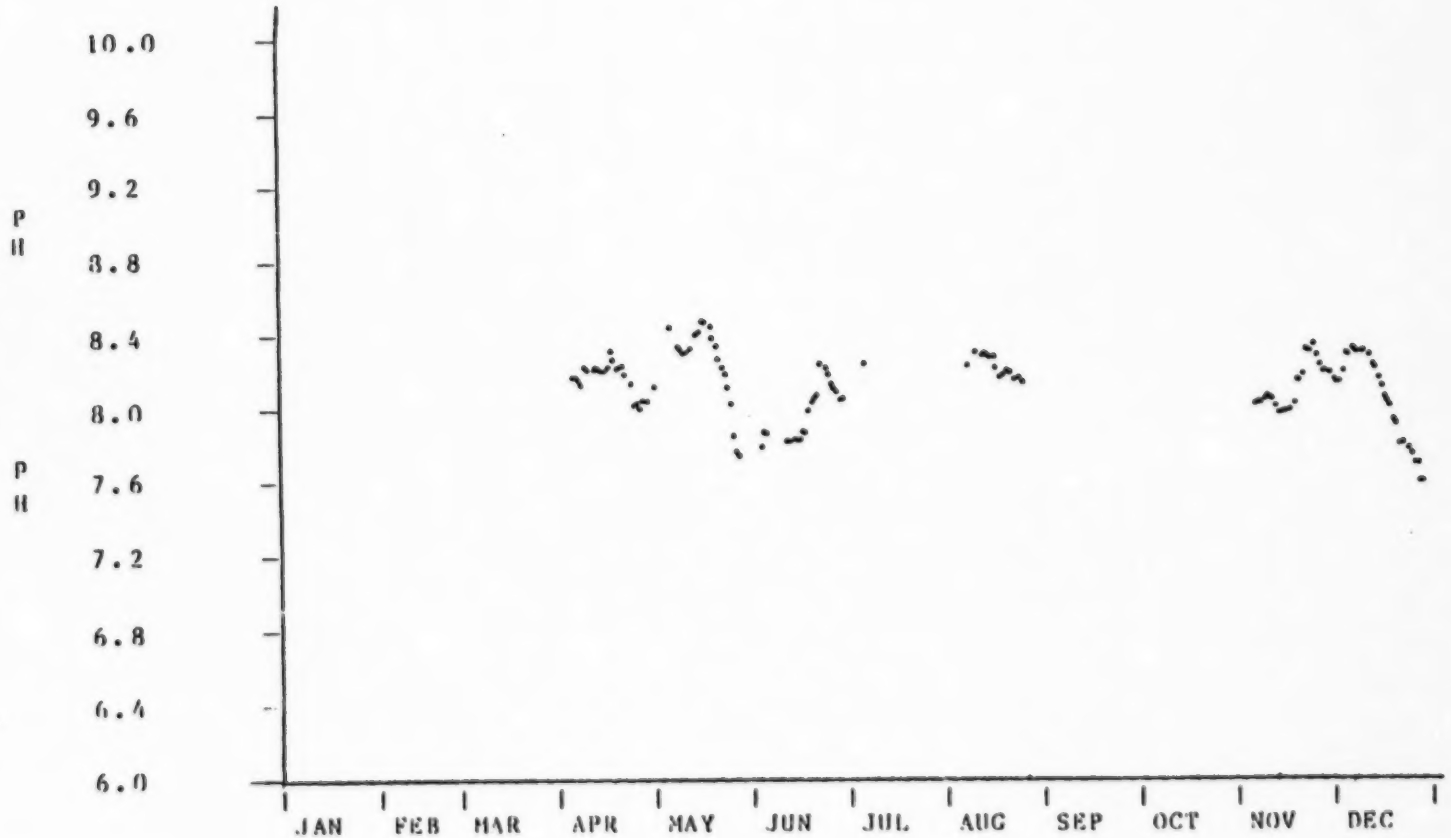

Figure 48. Mean Daily pH in the Souris River near Glen Ewen during 1981.

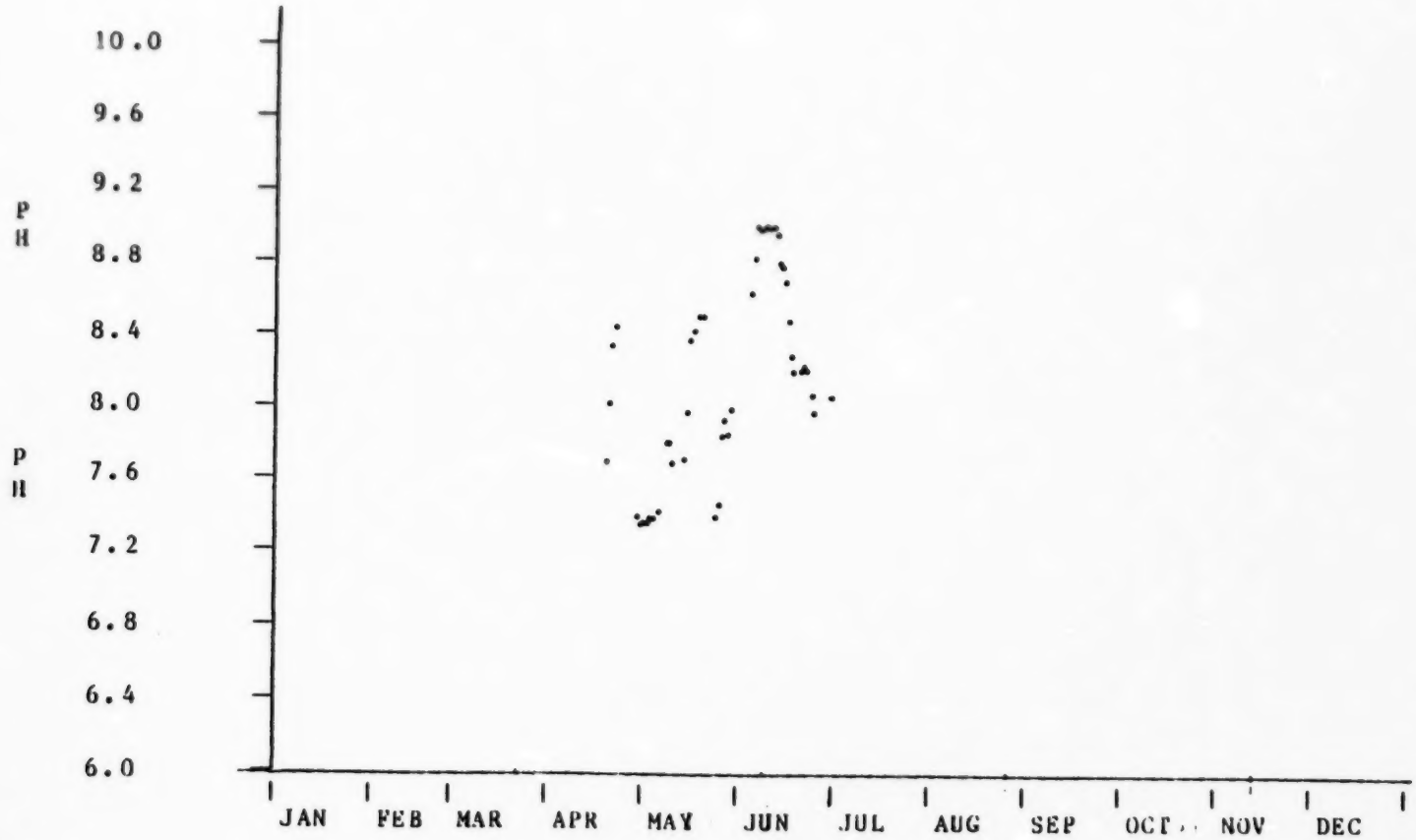

Figure 49. Mean Daily pH in the Souris River near Glen Ewen during 1982.

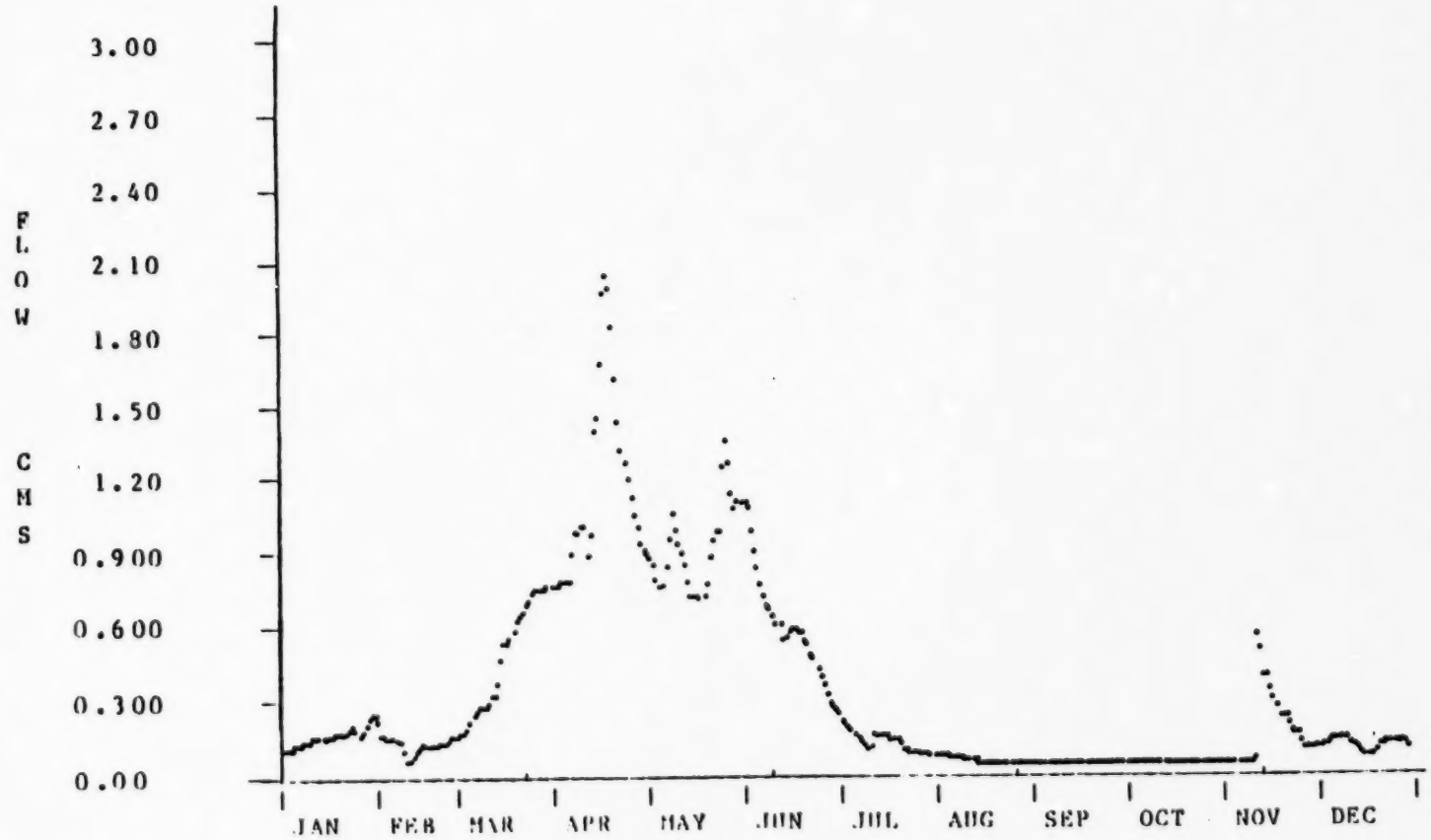

Figure 50. Mean Daily Flow in the Souris River near Glen Ewen during 1977.

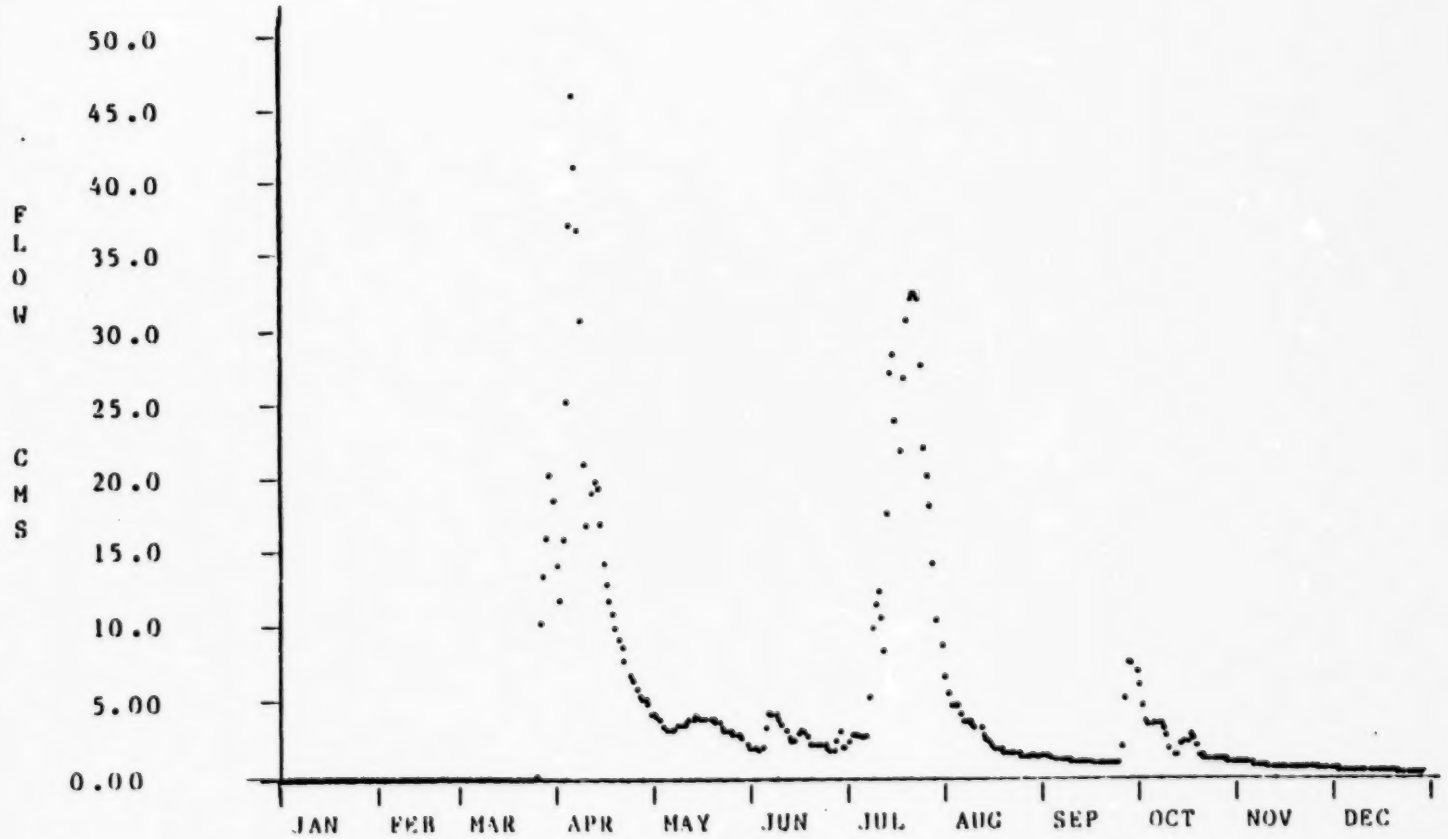

Figure 51. Mean Daily Flow in the Souris River near Glen Ewen during 1978.

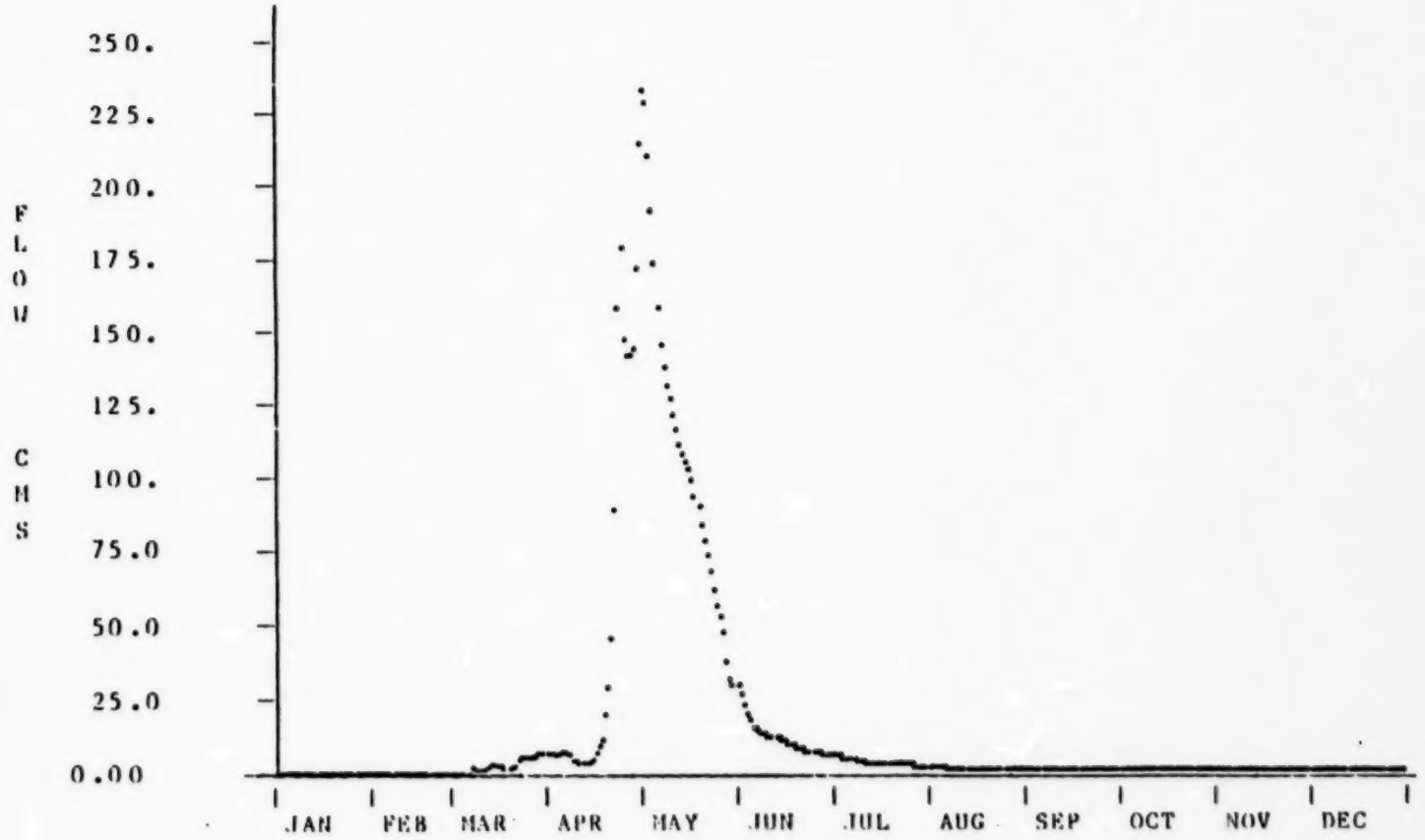

Figure 52. Mean Daily Flow in the Souris River near Glen Ewen during 1979.

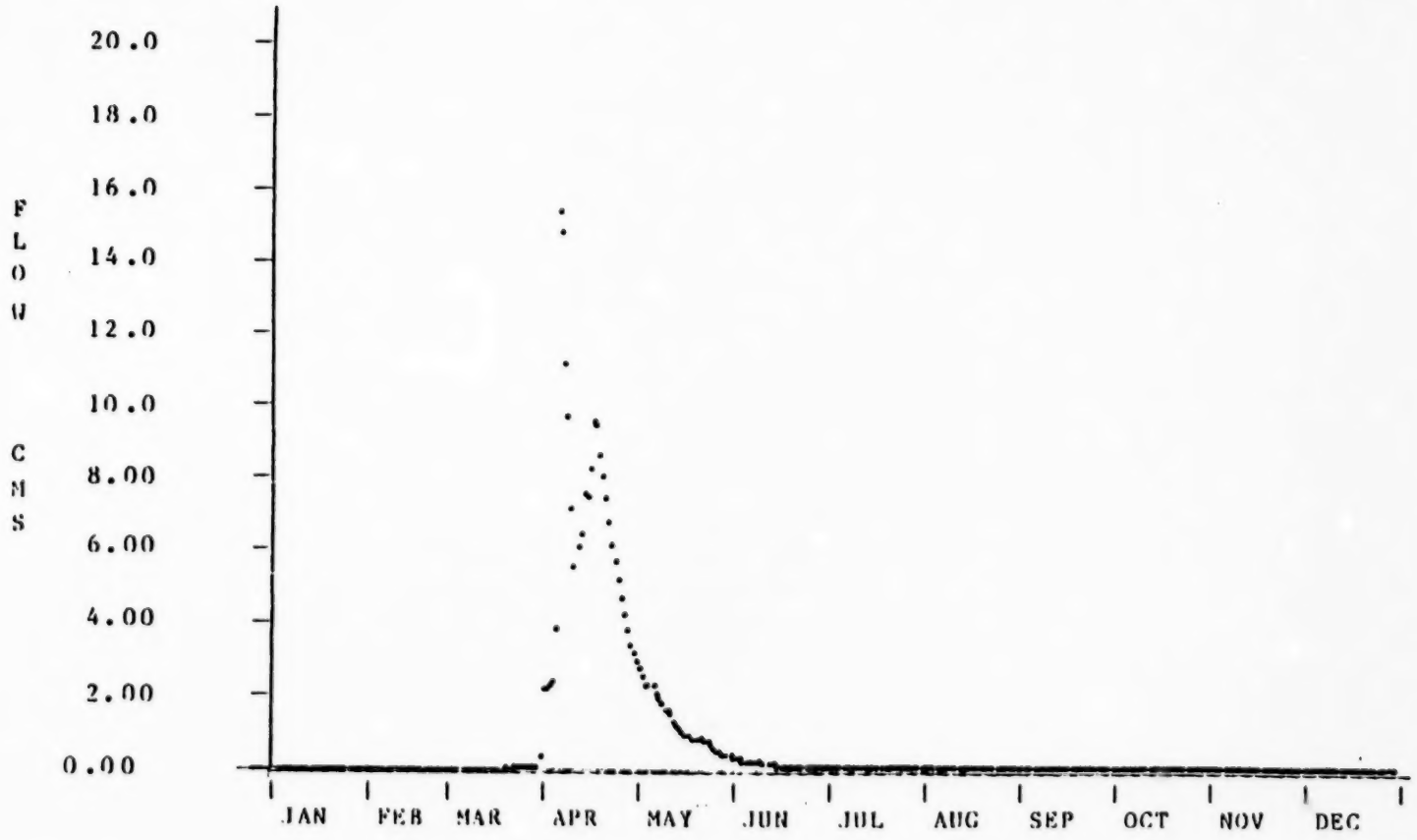

Figure 53. Mean Daily Flow in the Souris River near Glen Ewen during 1980.

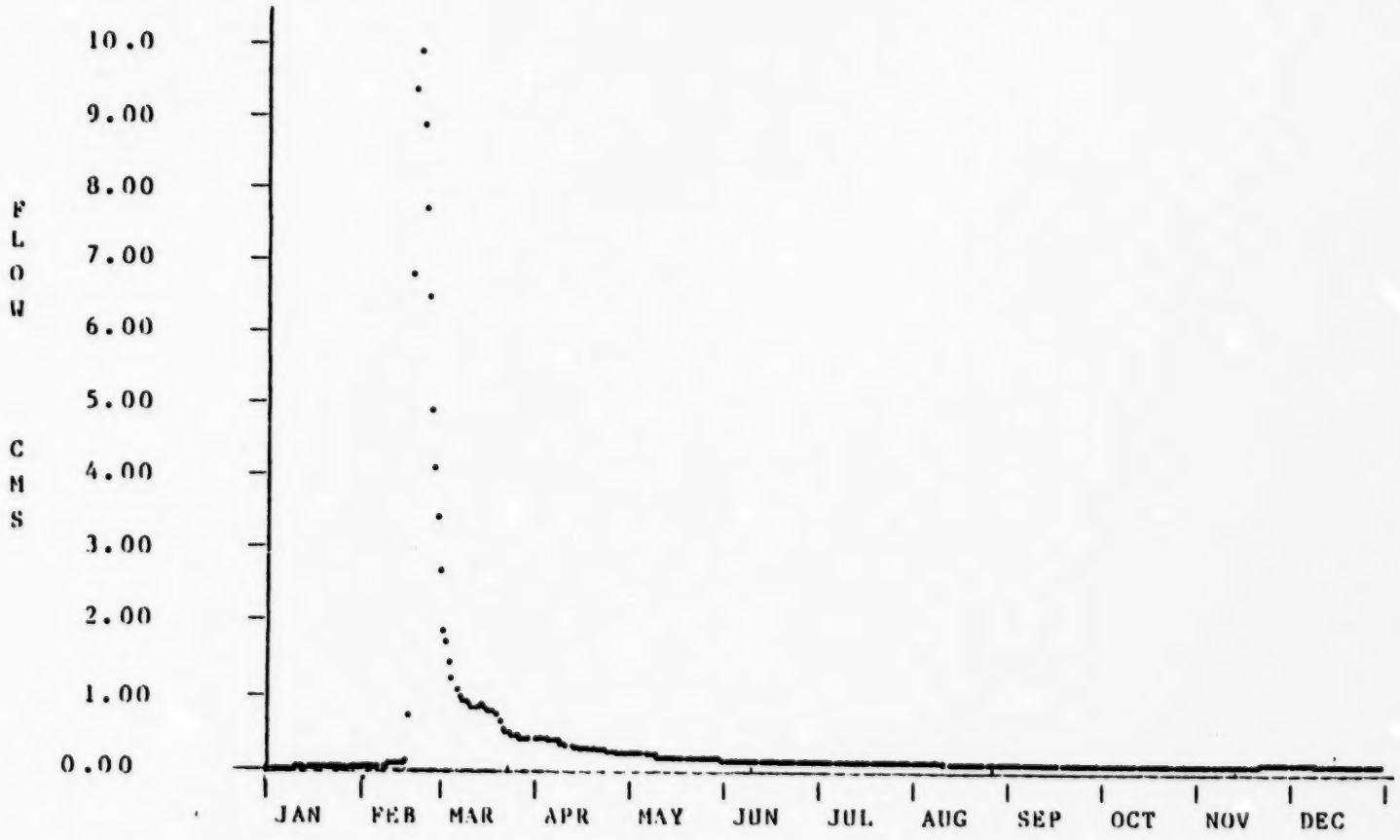

Figure 54. Mean Daily Flow in the Souris River near Glen Ewen during 1981.

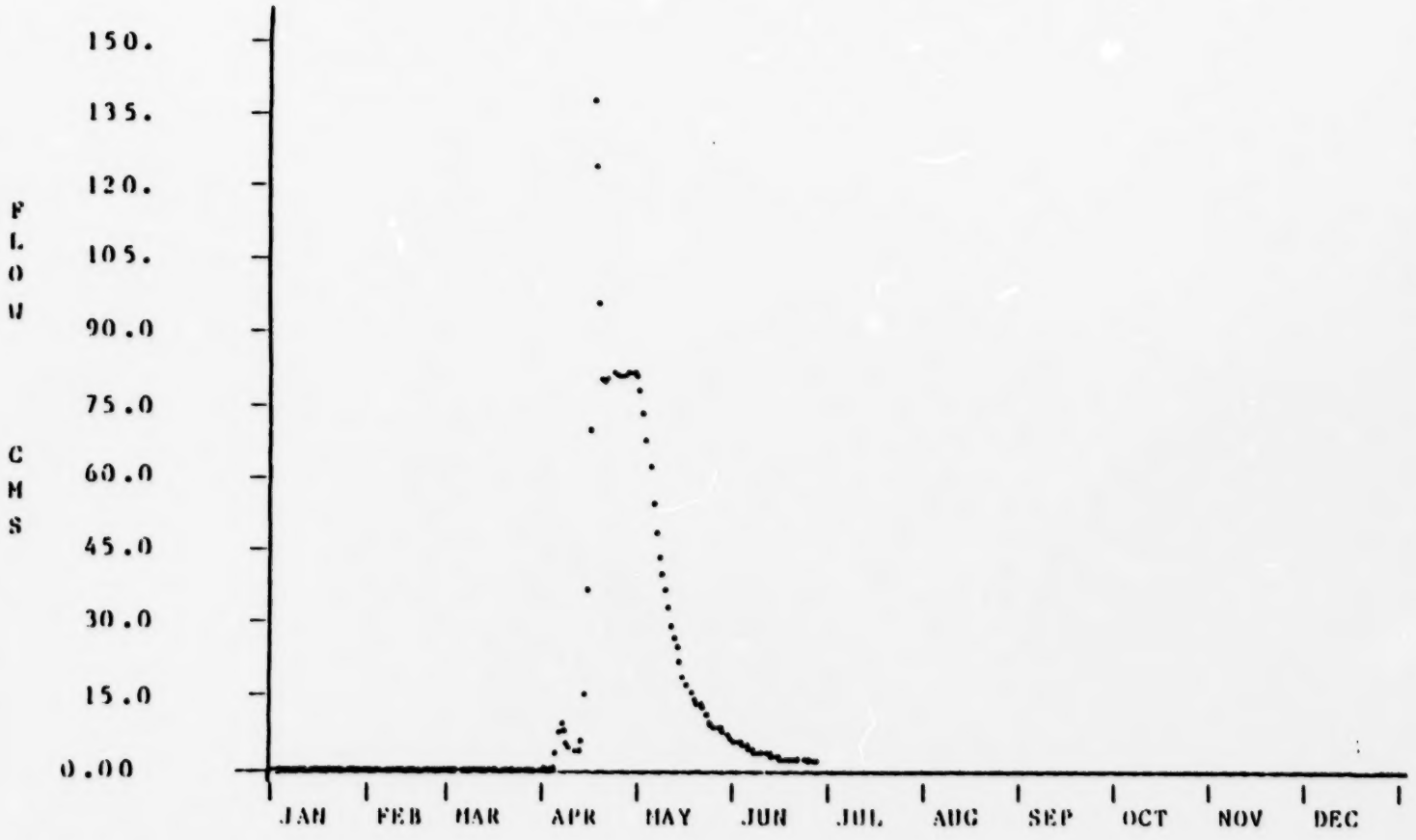

Figure 55. Mean Daily Flow in the Souris River near Glen Ewen during 1982.